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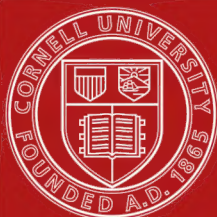
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DOMESTIC
SANITARY ENGINEERING
AND PLUMBING

BY THE SAME AUTHOR

HEATING SYSTEMS: DESIGN OF HOT WATER
AND STEAM HEATING APPARATUS

With Illustrations. 8vo.

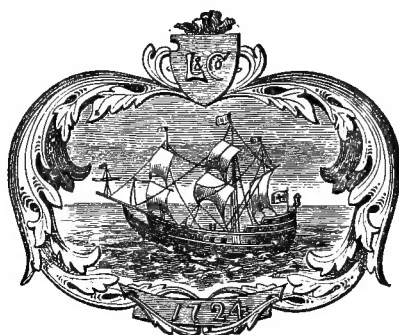
LONGMANS, GREEN AND CO.
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DOMESTIC SANITARY ENGINEERING AND PLUMBING

DEALING WITH DOMESTIC WATER SUPPLIES,
PUMP & HYDRAULIC RAM WORK, HYDRAULICS,
SANITARY WORK, HEATING BY LOW PRESSURE,
HOT WATER, & EXTERNAL PLUMBING WORK

BY

F. W. RAYNES



WITH 277 ILLUSTRATIONS

SECOND EDITION

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PREFACE

IN order to cover the subject without making the book unwieldy, and expensive to procure, it has been necessary to omit a great deal of elementary and general matter, and instead of devoting space to the Municipal side of Sanitary Engineering the scope of the work has been limited to the title of the book.

Many formulæ have been introduced as an aid in the design of work, and in most cases these have been given in as simple a form as possible consistent with accuracy, whilst numerous examples have been worked to show their application.

Although the book will be found valuable for Students of Domestic Sanitary Engineering and Plumbing for Examination purposes, the writer hopes that it will have a still greater value for those who are entrusted with the design, the supervision, and the execution of this branch of engineering work.

Much time has been entailed in the preparation of suitable drawings, and where a catalogue illustration has been used, it is not intended to convey that a certain manufacturer's goods are superior to those of another firm, but to illustrate some principle or point under discussion.

For valuable aid in the preparation of the illustrations the writer's thanks are due to his drawing assistant, Mr. John Burnside.

F. W. RAYNES.

THE GLASGOW AND WEST OF SCOTLAND
TECHNICAL COLLEGE, GLASGOW.

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DOMESTIC SANITARY ENGINEERING AND PLUMBING

CHAPTER I

MATERIALS AND THEIR PROPERTIES: MODE OF MANUFACTURE

A GOOD knowledge of the properties of materials is essential for executing work of importance where durability and sound workmanship are required. From time to time much work has resulted in failure owing to ignorance of the properties of the materials employed.

Metals.—The properties of metals are both physical and chemical. Physical properties are malleability, fusibility, ductility, tenacity, flow of metals, lustre, elasticity, electric conductivity, and heat conductivity.

Malleability is that property which permits of a metal being rolled into sheets, and worked into various shapes, without the metal being broken or torn.

Fusibility, as the term indicates, is the conversion of a solid into the liquid state by the application of sufficient heat. All metals, with the exception of mercury, are solid at normal temperatures.

Ductility is the property which permits a metal to be drawn into the form of wire; the thinner the wire can be drawn the more ductile is the metal.

Density is the relative weight of a body when compared with an equal volume of water. All the metals used in Plumbers' Work are heavier than water. Lead is the heaviest, having a density or specific gravity of 11·4; whilst aluminium

is the lightest, having a density of 2·67. In other words, volume for volume lead is 11·4 times heavier than water, and aluminium 2·67 times heavier.

Tenacity indicates that property which resists the particles or molecules of which a body is composed from being torn asunder. The tenacity of metals is greatly reduced when they are subjected to high temperatures.

Flow of Metals.—Although not visible to the naked eye, the molecules composing metals are, to a more or less extent, in a state of motion due to variations of temperature. Flow of metals is more pronounced when they are subjected to pressure; thus a piece of sheet lead can be thinned in one place and thickened in another, owing to the manner in which the molecules can be displaced by the application of the bossing stick or mallet. In other words, the metal is said to flow. It is on account of this property that a block of lead can be rolled into thin sheets, or forced through a die to take the form of a pipe.

Lustre.—All metals when clean or when polished reflect light, and therefore have a high lustre.

Elasticity is that property which permits of a metal regaining after distortion its original shape. Thus if a steel bar is only bent or elongated by the application of force, the bar will regain its normal state when the force is removed, provided the elastic limit of the metal has not been exceeded. When the elastic limit has been passed a permanent set is made.

Conductivity.—Metals are good conductors of both heat and electricity, although some are much better than others. Copper ranks as the best conductor of the common metals for either heat or electricity, whilst lead is about the worst.

Chemical Properties.—When in the molten state the common metals have a great affinity for oxygen, with the result that oxides of these metals are rapidly produced. Dry air does not affect metals at normal temperatures to any considerable extent, but when the air is moist, and carbonic acid is present, the surfaces of metals are readily attacked and covered with a film of oxide.

Acids, such as Nitric, Hydrochloric, and Sulphuric, tend

to dissolve the common metals to a more or less extent. Sulphuric acid when cold only slowly affects lead, owing to sulphate of lead forming on the surfaces and acting as a protective covering to the metal beneath.

Lead and its Ores.—The ores which are capable of yielding considerable quantities of metallic lead are Galena and Cerusite. The former is a dark-coloured, metallic looking substance, and is the most widely distributed. Cerusite occurs as a carbonate of lead in the form of a white or dark earthy substance, and intermixed with clay and limestone, etc.; galena is also often present in its admixture. Galena (PbS) is a compound consisting principally of lead and sulphur, and when this ore is placed in the smelting furnace it contains from 70 to 85 per cent. of lead. Cerusite (PbCO_3), or white lead ore, is a compound consisting chiefly of lead, oxygen, and carbonic acid gas. The pure ore will yield as much as $77\frac{1}{2}$ per cent. of lead, whilst the crude ore contains about 30 per cent. of lead. Although galena is very widely distributed, it does not occur in many places in sufficient quantity to pay for working it. The principal British localities where lead is obtained are North Wales, Derbyshire, Cornwall, Northumberland, Lanarkshire, and Laxey, Isle of Man. Large quantities of lead are imported to Great Britain from Spain. Cerusite is found in large deposits in Nevada and in Colorado, U.S., and it also occurs in Scotland, principally at the Lead Hills, Lanarkshire. The lead of commerce, however, is obtained usually from galena.

Reduction of Ores.—Lead is extracted from the ore in smelting furnaces, which differ in operation and construction in different localities, and according to the nature of the impurities in the ore. The impurities lead contains are silver, iron, zinc, antimony, and copper, etc., and these render the lead very hard. All the impurities, with the exception of silver, can be removed by raising the lead to a high temperature in the presence of air, when oxidation of the impurities takes place at the surface and they can be taken off in the form of a scum. To extract the silver, the lead is usually subjected to either the Pattinson or Parkes

process. The object aimed at in each process, is to concentrate the silver into a small quantity of lead, when the rich argentiferous lead is afterwards finally freed from the silver by cupellation. A little impurity in lead, however, is not always objectionable. In the case of sheet lead for roof work, and where it requires to be worked into various shapes, the metal should be as free from impurity as possible. Soil pipes which require bends made in them should also be of soft lead. Lead water pipes, on the other hand, and which deliver water under more or less considerable pressure, are better made of lead which contains a little impurity. In this case the harder pipes better resist the erosive action of water when flowing through them at high velocities. Thick sheet lead and plate lead, which is used for lining vitriol tanks, is said to better resist the action of the acid when it contains a small percentage of antimony.

Physical Properties of Lead.—In colour lead is bluish-gray, and when newly cut has a bright metallic lustre, but is rapidly oxidised in the presence of moist air. Lead is not very ductile, so it cannot be drawn into very thin wire; it has a low tenacity, and is useless where strength or toughness is required. The specific gravity of lead is about 11.4, and a cubic foot weighs approximately 712 lb. It is not a perfectly elastic metal, and the rate of expansion slightly exceeds that of contraction. The latter property is noticeable in many lead-lined sinks, where the metal has formed itself into ridges or buckles owing to its size being intermittently increased. Many lead pipes are either distorted or fractured by increase of length due to alternate heating and cooling. Lead is a poor conductor of heat and electricity, but it is very malleable and soft, and can be readily worked into various shapes without the application of heat.

Chemical Properties of Lead.—To a more or less extent lead is acted upon by all acids, and also by moist air. After lead has been newly laid in gutters, or fixed in connection with other roof work, it is generally found that on the following day the surfaces of the lead are covered with a thin film of basic carbonate of lead; this film is due to the moisture and carbonic acid gas in the atmosphere acting

upon the lead. The action readily takes place after sunset when dew is deposited, or in the daytime when the atmosphere is in a saturated state. Sheet lead work always has a better appearance a day or two after it has been done, owing to the carbonate film producing a dull surface and obscuring tool marks.

Water, when pure, is said to have no action upon lead, but when it contains free oxygen the lead is attacked, forming an oxide which is soluble in water. If carbonic acid gas is also present in the water, the dissolved oxide is precipitated as basic carbonate, and the surfaces of the lead are again laid bare to the action of the water. Impurities in water act differently; some tend to prevent water acting upon lead, whilst other impurities tend to accelerate the action.

Sulphuric acid, when dilute, has no action upon lead; strong solutions of the acid at ordinary temperatures act slowly upon it, but the action is accelerated by the concentration of the acid and with rise of temperature. Boiling sulphuric acid readily converts the lead into a sulphate with the evolution of sulphurous acid. Lead is readily dissolved by dilute nitric acid, and it is also acted upon by hydrochloric acid.

Lead Compounds.—The principal lead compounds, so far as plumbers are directly concerned, are red lead and white lead; the former is an oxide of lead, whilst the latter is a carbonate of lead. These two compounds are largely used by plumbers for jointing materials.

Red Lead.—(Pb_3O_4) is made by exposing molten lead in a furnace to the action of the air; as oxidation takes place the metallic surfaces are repeatedly renewed by pushing the oxide towards the back of the furnace, this operation being continued until apparently the whole of the metallic lead is converted into an oxide. It is then removed from the furnace to the grinding mill, where it is ground in water with heavy, revolving stone rollers. The grinding process, besides reducing the oxide into a fine state of division, separates the oxidised from any metallic lead which may be present. After leaving the grinding mill the oxidised lead is put into a furnace which is called the colouring oven, and which has

a temperature of about 600° F. In this oven the oxide is exposed to the action of the air for about twenty-four hours, in order that it may take up a further amount of oxygen, which is absorbed at a gradually decreasing rate until oxidation is complete, and the oxide has assumed a bright red colour. The red lead is now removed from the colouring oven and reground in water, and afterwards dried.

Litharge (PbO) is made precisely in the same manner as red lead, excepting that the furnaces are raised to a higher temperature. Litharge is yellow in colour.

The difference in colour of red lead and litharge is due to the different amounts of oxygen which have entered into their compositions.

White Lead (PbCO_3) is made in different ways, but the Dutch process is the one best known. In the Dutch process either specially cast grids of lead, or sheet lead loosely formed into coils, are placed in jars which contain acetic acid. The lead is fixed clear of the acid, and the jars are arranged in rows and built up in stacks. At the bottom of the stack a thick layer of fermenting material, such as tan, is placed, and upon this the jars are arranged side by side, and surrounded with the same material. Over the mouths of the jars thin lead plates are fixed, and then another floor is formed by laying boards on the top of the jars. On this floor another layer of tan is placed, and other jars are arranged as above described. The jars are built up in tiers in this way until the stack is sufficiently high. When complete, the stack is left for about three months, during which time fermentation takes place, and the whole mass becomes thoroughly heated. The heat generated in the stack vaporises the acetic acid, and as the vapour combines with the carbonic acid gas given off by the decomposing tan, the metallic lead is attacked and converted into a basic carbonate of lead. In due time the corroded lead is removed from the jars, and freed from any metallic lead by passing it between corrugated rollers. The grinding process is the next operation, and if the lead is required in the form of paste it is reground in linseed oil.

Lead Pipes.—For purposes of comparison lead pipes may be divided into four classes, viz: First, ordinary lead pipes;

second, lead pipes which have one or both surfaces tinned; third, tin-lined lead pipes where the tin and lead are in contact; and fourth, tin-lined lead pipes where the tin and lead are separated by a covering of asbestos or similar material.

Lead pipes are made by the aid of the hydraulic pipe press, hand-made pipes being now a thing of the past. The manufacture of lead pipes is apparently a simple process, but great care is required when setting the die and core of a machine, in order that a pipe will be turned out as nearly true in section as possible.

In Fig. 1 a lead pipe making machine is given. Its principal parts are the ram P, container C, the core or mandril M, and the die D. Molten lead is run into the container C until the latter is filled and, as a rule, holds just sufficient lead to make two bundles of half-inch pipe. The lead is allowed to solidify, but whilst still hot hydraulic pressure is brought to bear upon the ram P, and to raise the piston. From the rising container the lead only has one point of escape, and that is through the annular space between the mandril and the die. Through this space the lead issues in the form of a pipe. The die D, it will be observed, forms the external diameter of the pipe, whilst the mandril M makes the bore. It is often thought by people who have had no opportunity of seeing pipes being made, that the lead is forced from the container whilst in a molten state; this, however, is not the case, as the lead would be simply squirted into the air. Considerable pressure is required to form a pipe, the intensity of the pressure varying with the size of pipe and the amount of impurity in the lead. Small pipes, other things being equal, require a greater hydraulic pressure than larger sizes to produce. When water pipes are being made, they are wound round drums into bundles as they issue from the machine. For making soil and waste pipes in straight lengths, a cord is passed over a pulley which is fixed high over the machine; one end of the cord is attached to the pipe, and the other is kept taut by a man as the pipe is being drawn; another person measures the pipe and cuts it off to the required length.

Lead pipe making machines differ considerably in structural details, but their general mode of operation is practically the same in each case. By changing the die and mandril, one machine can be used for making various sizes and thicknesses of pipes.

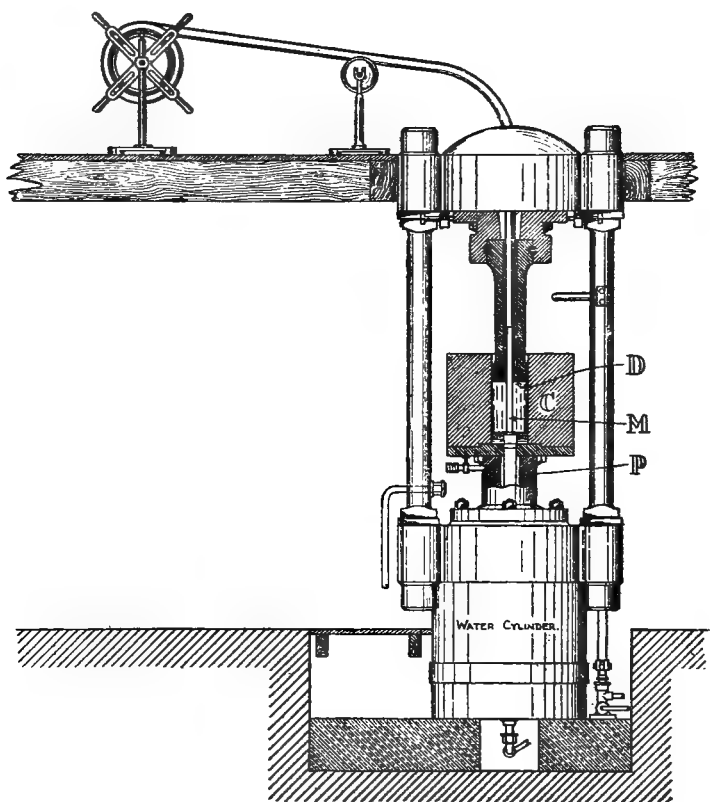


FIG. 1.—Machine for making lead pipe.

Tinned Lead Pipe is sometimes confused with tin-lined lead pipe, but in the former the surface of a pipe is only covered with a thin film of tin, whilst in the latter the tin lining may form a substantial part of the pipe. The tinning process is very simple, and is effected as the pipe issues from the machine. When the inner surface of a pipe requires to be

tinned, all that is necessary is to pour a little molten tin inside the pipe; the hot mandril and lead keep the tin in the molten state, and as the pipe is being formed its inner surface is covered with a film of the molten tin.

When this class of pipe was first produced it was thought that the covering of tin would tend to prevent the corrosive action which some waters have upon lead. Instead, however, of the tinning preventing such action, it was soon discovered that this superficial treatment often tended to accelerate it. At their best, internally tinned lead pipes are little or no better than those which are not tinned; the tin alloys to a more or less extent with the lead, but the interior surfaces of the pipes are not evenly covered. To tin the outer surface of a lead pipe, the die of the machine is frequently formed with a hollow, or pocket, into which molten tin is poured. Sometimes the tin is melted in the upper part of the machine by heating it with gas, or by other means. In the hollow of the die block the molten tin surrounds the pipe, and as the latter passes through it the external surface of the pipe receives its film of tin. To remove any superfluous metal, and to give the pipe a smooth appearance, cotton waste or similar material is pressed against the pipe as it issues from the machine.

Lead gas-pipe which has its external surface tinned is frequently called composition pipe, but the term "composition" is rather misleading in this case.

Tin-Lined Lead Pipe is also made by the ordinary pipe press, Fig. 1; but in this case a double process of charging the container C is involved. Instead of the container being fully charged with lead, an annular space next the mandril M is left, and is afterwards filled with molten tin. Thus whilst in the container the lead and tin really take the form of a very thick, tin-lined lead pipe. The tin is added after the lead, and when set hydraulic pressure is brought to bear upon the under side of the container, and as the latter rises the two metals are forced together through the die, and issue in the form of a compound pipe, with the tin and lead in the correct proportion. The thickness of the tin lining varies from about $\frac{1}{32}$ inch to $\frac{1}{16}$ inch, according to the size and quality of the pipe.

Tin-lined lead pipes have in the past been largely used to

minimise the risk of lead poisoning where portable waters dissolved the latter metal. Although these pipes are superior to lead ones for conveying waters which attack lead, still they are far from being satisfactory, as traces of the latter metal will generally be found in water which has been lying stagnant in them for a short time. It is also possible for imperfections to occur during the manufacture of tin-lined lead pipe, and doubtless a certain amount of alloying takes place when the molten tin comes in contact with the lead during the charging of the machine. Another drawback generally arises through the unsatisfactory method of jointing these pipes, owing to the lead being laid bare in the neighbourhood of the joints by the tin lining being destroyed. It is therefore obvious that the use of tin-lined lead pipe is no guarantee that a soft and acid water which passes through it will not contain traces of lead. On the other hand, if a water has no effect upon lead, tin-lined lead pipes serve no very special purpose excepting that they are stronger than lead pipes.

Insulated Tin-Lined Lead Pipes.—Some time ago an attempt was made to overcome the defects of ordinary tin-lined lead pipe by producing a pipe in which the tin and lead are separated by an asbestos lining. It is not possible, in this case, for the tin and lead to alloy when making the pipe, as the tin and lead tubes are separately made. The tin lining is afterwards covered with the asbestos, and the lead pipe requires to be of sufficient size to receive them. The composite pipe is then formed by inserting the insulated lining into the lead casing, and by afterwards passing the whole through a special machine the three materials are compressed together. This form of tin-lined lead pipe overcomes some of the failings of the first kind, but it is not free from defects, and trouble has been caused by the tin lining collapsing and the water passages becoming stopped. A great amount of care is also necessary in making the joints, in order to prevent water coming into contact with lead at these points. It also has the drawback of a high initial cost, and, like the ordinary form of tin-lined pipe, is more costly to fix than lead pipe, on account of the special fittings required and extra time involved in making the joints.

Where water is known to act upon lead, it is undesirable to use lead pipes of any form for distributing water which is intended for dietetic purposes. The best form of pipe at present in use for the conveyance of such water is the tin-lined iron pipe with right- and left-hand screwed and socketed joints.

Lead Traps and Bends.—Lead traps, which are used at the present time, are the seamless, hydraulically drawn productions, and the cast types; hand-made lead traps with soldered seams have had their day. The seamless traps possess the advantages of cheapness and smoothness, whilst those which are cast have the merit of being stronger than the former. Opinions still differ amongst many good plumbers with regard to the merits and demerits of the hand-made and machine-made trap. It is contended by some that the modern drawn seamless trap will not withstand the strain due to changes of temperature to the same extent as the hand-made trap with soldered seams; that the former has often failed in a comparatively short time, whilst hand-made traps fixed under similar conditions have been much more durable. These views are worthy of consideration, because if a certain fitting fails in a comparatively short time when compared with a similar one which is only made in a different way, the cause of such failure should not be difficult to ascertain. Very often when comparisons are made some of the most important factors are overlooked, and thus the conclusion arrived at may be only partly true. It is quite possible, however, for a hand-made trap to be much more durable than a drawn one under certain conditions, but the writer sees no reason why a seamless trap under ordinary circumstances should not be just as durable as a hand-made one, provided it is properly fixed, made of good lead, and of sufficient strength. Thickness for thickness, hand-made traps are stronger than those which have been drawn, owing to the soldered seams, which impart a fair amount of rigidity. Should a trap with soldered seams be fixed in connection with a length of light lead waste pipe, and the pipe arranged that movement due to expansion and contraction can freely take place, the trap under such conditions may have a long life, and especially

if the waste water passed through it is not of a very high temperature. On the other hand, if the same trap had been fixed to a length of strong waste pipe, through which very hot water was discharged, and no provision were allowed for the pipe to expand, the life of the trap under the new circumstances would be comparatively a short one. In the latter case the whole of the strain which accompanies expansion would be concentrated upon the trap, and the latter would naturally be distorted by the gradual increasing length of pipe.

If, now, we assume that drawn lead traps had been used for the cases already described, the results would be similar in each. Of course it is quite possible for special cases to occur where greater distortion can take place with drawn lead traps than with those with soldered seams, but where a strong form of lead trap is desirable a cast one could be used. Lead is not, however, an ideal material for traps which receive alternately hot and cold discharges of water; and where durability is an important factor, iron or brass traps should be used.

For general work the cheapness of drawn lead traps, and the many forms in which they are made, are important advantages. Their life may also be considerably increased if the waste pipes are arranged to prevent the pull and thrust which accompany contraction and expansion being concentrated upon the traps.

The cause of the defects of many old, seamed lead traps, which have been taken out from time to time, instead of being due to different rates of expansion and contraction between the two different materials of which they were constructed, were chiefly the result of corrosion owing to lack of ventilation.

Drawn lead traps should not be thinner in substance than 6-lb. sheet lead, and a greater thickness as a rule does not proportionally increase the life of traps. Much, of course, depends whether the metal is pure or not. For example, it is quite possible for a trap which is equal to 8-lb. sheet lead to be less durable than one whose thickness is only equal to 6-lb. lead, provided the lead of the former contained a higher percentage of impurity than that of the latter.

The manufacture of drawn lead traps and bends is similar to that of ordinary lead pipe, but the machines differ in construction. In a trap making machine the lead container is arranged with a piston at each end, whilst the lead issues at the centre of the machine. After the container is charged with lead, hydraulic pressure is brought to bear upon the pistons, and by manipulating the pressure on each piston the issuing pipe can be curved or bent in the direction desired. When equal pressures are applied to the pistons the lead issues from the machine in the form of a straight pipe, and when differential pressure is acting on the pistons the pipe curves in the direction of the greater force.

Sheet Lead.—This may either be cast or milled, but the former is very seldom required at the present time, and it is very doubtful if $\frac{1}{4}$ per cent. of the present day plumbers will ever be called upon to cast and lay it. Cast sheet lead when required can be made on a suitable casting frame in the workshop, or other suitable place; or it may be procured from a lead merchant.

Cast Sheet Lead.—For roof work cast sheet lead is considered by some to be superior to milled sheet lead, but on the whole its drawbacks outweigh any merits it may possess. Cast lead can only be made in comparatively small sheets, it requires to be thicker than milled lead, it is not as a rule of uniform thickness, and sometimes it is porous. It is also dearer than milled lead, and neither does it permit of the same neatness of finish when it requires to be worked into various shapes. The chief advantages of cast lead are its appearance from an architectural standpoint, and it will expand and contract with less risk of breaking than milled sheet lead. The latter is due to the fact that the molecules of cast lead are in normal positions, whilst those of milled lead are squeezed into unnatural places, and may be more or less in a state of internal stress.

Milled Lead is made in sheets about 33 feet long and from 7 ft. 6 in. to 8 feet in width. Some few rolling mills make sheets up to about 40 feet in length and 9 feet in width. Narrower sheets than those usually made can be

obtained if desired, and special widths are often an advantage as scrap can in many cases be reduced.

Milled sheet lead is made by first casting a block of lead approximately 8 feet square and 6 inches in thickness. After this has cooled sufficiently it is hoisted on the rolling machine, and passed forwards and backwards between two heavy chilled steel or cast-iron rollers, which are located in the centre of the frame-work of the machine. The rolling process is continued until the block of lead has been reduced to about three-quarters of an inch thick. The flow of the metal, due to the enormous pressure which is brought to bear upon it, is practically all in a longitudinal direction; as regards the width, that is not much affected, the edges only taking a ragged or irregular form. When the thickness of $\frac{3}{4}$ inch has been reached, the lengthened plate of lead is cut cross-ways into suitable lengths, which vary with the size of the finished sheet and strength of lead required. Very often two sheets are rolled at one operation; this is done by rolling one of the pieces, into which the whole plate has been divided, until its thickness is equal to about that of 10-lb. sheet lead; at this point the sheet is doubled, when by further rolling the desired thickness is obtained. The ragged edges are now straightened and the lead rolled up. When lead thicker than 6 lb. per sq. foot is required the sheets are usually rolled separately. Fig. 2 gives drawings of a milling machine. It will be observed that numerous wood rollers are arranged from end to end of the machine, and these carry the lead, and of course impart easy motion to the lead when being rolled. Pressure is applied to the centre rollers by the aid of a wheel and suitable gearing, and the top roller is raised and lowered by the same means.

The cutting roller, which is shown on the right side of Fig. 2, is for trimming the edge of a sheet. One is fixed on each side of the machine, and occasionally a guillotine arrangement is also provided for shearing the sheets cross-wise.

Iron.—The principal ores from which iron is obtained are Red Hematite, Brown Hematite, Magnetic Iron Ore,

LEAD ROLLING MILL.

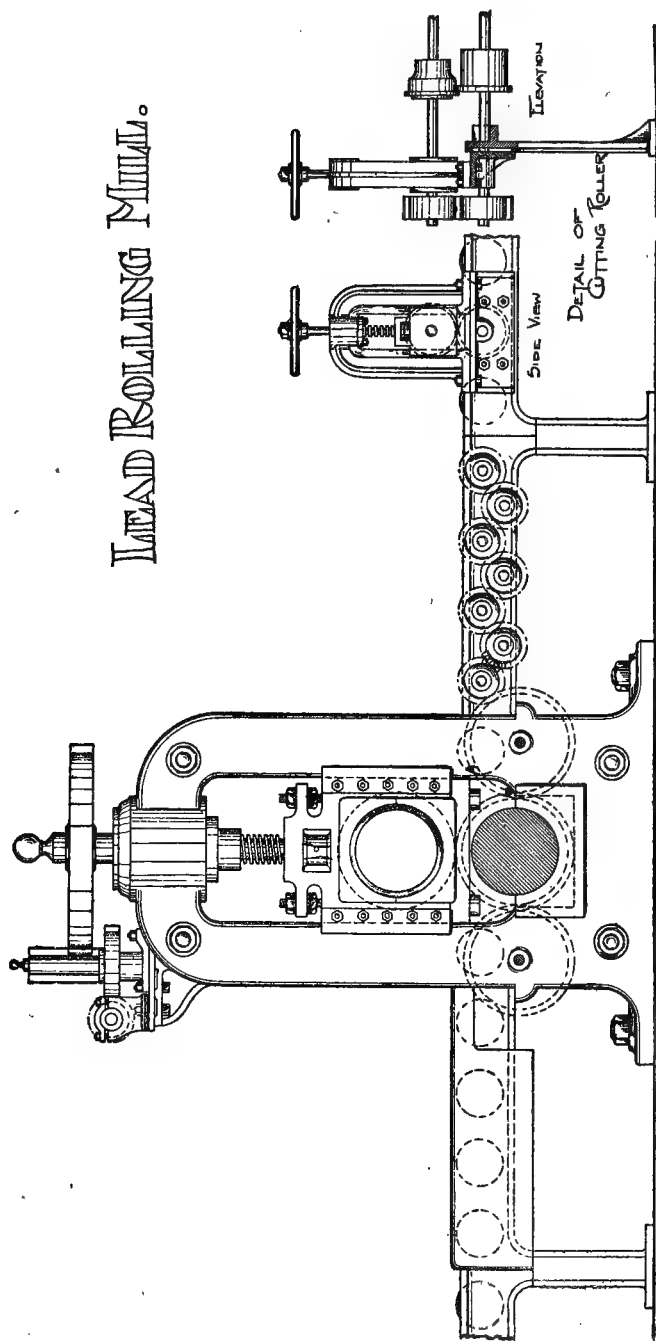


FIG. 2.

and Siderite. The first three occur as oxides of iron, whilst the latter occurs as a carbonate of iron.

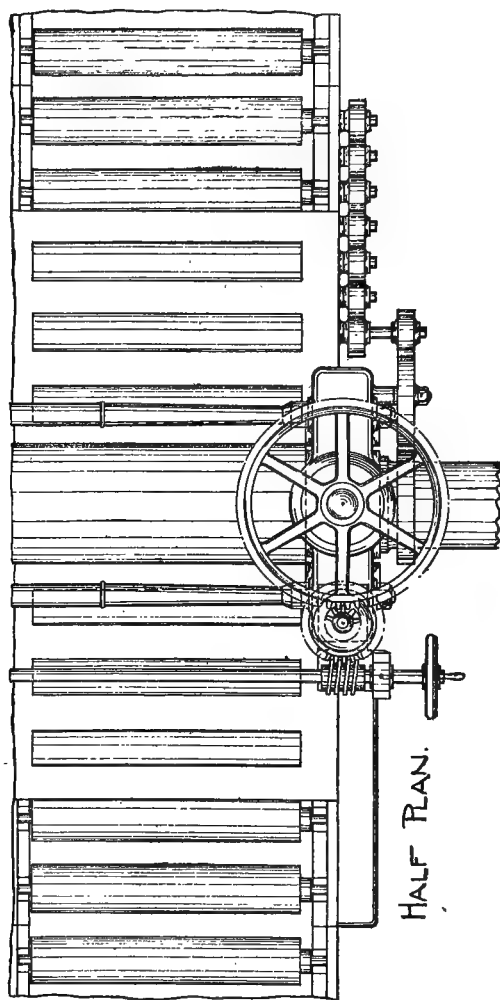


FIG. 2a. —Lead Rolling Mill.

Iron takes three principal forms, viz.: Cast Iron, Wrought Iron, and Steel. The difference in their physical and chemical properties is due chiefly to the difference

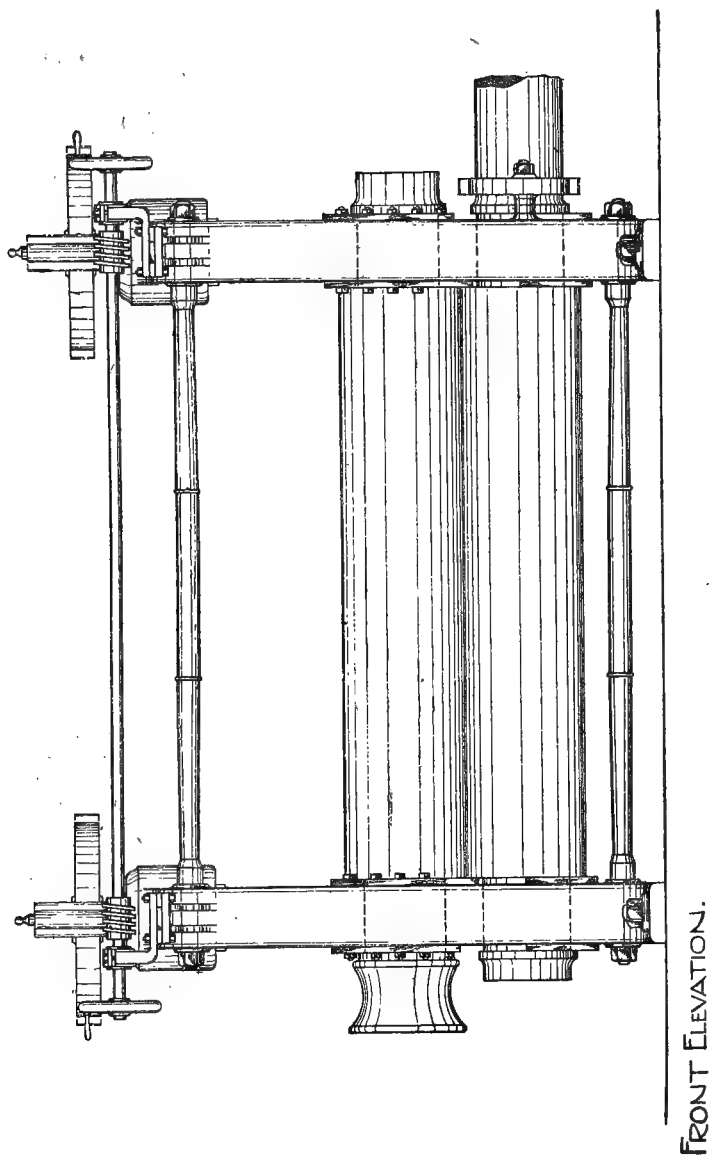


FIG. 2b.—Front view of cast-iron rollers of Rolling Mill.

in the amount of carbon which enters into their composition.

Cast iron contains over $1\frac{1}{2}$ per cent. of carbon, and a large amount of other impurities. Wrought iron is the purest form of iron, and only contains about $\frac{1}{2}$ per cent., and less, of total impurities; the amount of carbon should not exceed $\frac{1}{2}$ per cent. Mild steel contains less than $\frac{1}{2}$ per cent. of carbon, whilst hard steel contains from $\frac{1}{2}$ per cent. to about 2 per cent. of carbon. Both forms of steel are nearly free from other impurities.

The principal impurities in iron are carbon, manganese, phosphorus, silicon, and sulphur. Cast iron at the present time is very largely used in the manufacture of sanitary fittings, such as baths, lavatories, etc.; for drainage work, soil and waste pipes, and for boilers, pipes, and fittings in connection with low pressure hot-water and steam-heating work.

Properties of Iron.—*Cast iron* is hard and brittle, and varies in colour when fractured from a silver white to a dark gray. On account of its fusibility it can be run into moulds so as to take various forms. The specific gravity of cast iron varies from 7 to 7·6, and a cubic foot weighs from 437 to 474 lb. Its tensile strength is comparatively low, whilst its resistance to a crushing force is high; on an average the tensile strength of cast iron is about 7 tons per sq. inch, whilst the average crushing load is about 48 tons per sq. inch. Cast iron is less affected by oxidation than either wrought iron or steel.

Wrought iron is of a bluish-white or bluish-gray colour, and it is readily oxidised with moist air. It is very malleable and ductile, and at high temperatures can be forged, rolled, and hammered into various shapes. The average specific gravity of wrought iron is 7·78, and it weighs 485 lb. per cubic foot. Its average tensile strength is 22 tons per sq. inch, whilst the average crushing load is only about 17 tons per sq. inch. It requires a very high temperature to effect its fusion and, unlike cast iron, cannot be run into moulds.

Steel may be hard or soft according to the amount of

carbon it contains. Like wrought iron, it can be forged and welded; it is malleable, ductile, and very tenacious. Its colour is bluish-gray, and it is readily oxidised upon exposure to moist air. Ordinary steel can be tempered to take different degrees of hardness by cooling in liquids such as oil, water, etc. The tensile strength of ordinary steel is about 50 tons per sq. inch, and its crushing load is about 150 tons per sq. inch. The strengths of mild steel vary considerably, and whilst they are much less than those of ordinary steel they exceed those of wrought iron. The tensile strength of mild steel varies from 25 to 35 tons per sq. inch.

Malleable Cast Iron is largely used for fittings in connection with wrought iron tubes, for pipe hangers, clips, and brackets, and for many other purposes. The property of malleability is imparted to cast iron by decarbonising it. To effect decarbonisation the cast fittings may be embedded in hematite or oxide of manganese, and subjected to a red heat for a period which varies from a few days to several weeks, according to the size of the casting to be treated. This annealing process is also said to increase the tensile strength of the iron to about 1.6 times that of cast iron.

Iron Pipes are made of either wrought or cast iron, according to the purposes they are intended to serve and the pressure they are required to withstand.

Wrought-iron pipes are of two kinds; the first are those which have ordinary welded joints, and the second are those which have specially strong lap welded joints. The former are used for general work, such as for conveying water, gas, or steam; whilst the latter are for withstanding high pressures, as in hydraulic work, and for small bore hot-water heating apparatus.

Cast-iron pipes may be classified under three heads. Firstly, those which are cast in a horizontal position; secondly, those cast on an inclined plane; and thirdly, those which are cast in a vertical position. Pipes coming under the first head are chiefly those of a light character, such as rain-water pipes; frequently such pipes have thick and thin sides, owing to the cores being buoyed or bent

upwards when the metal is flowing into the moulds. Under the second heading fall the heavy section cast-iron soil, waste, and drain pipes; many water pipes are also cast in this position. When pipes are cast on an inclined plane the socket end is at the higher point, and the pipes produced in this way are superior to those cast in a horizontal position.

Water pipes which are required to withstand high pressure should be vertically cast, and the best and most reliable cast pipes are produced in this way. Vertically cast pipes have their socket ends downwards; their cores should be well and truly formed, and they should also be cast at least one foot longer than their finished lengths. The extra length is to ensure compactness of grain at the spigot end of the pipes, and it should be cut off afterwards in a lathe. The pipes should be true in section, and be free from defects and flaws of all descriptions. It is very important that pipes for conveying drinking water be coated with a suitable preservative immediately after casting, and before their surfaces are covered with a film of rust. Pipes should be tested before leaving the foundry to not less than twice the pressure to which they will be subjected when laid or fixed in position.

Coatings for Iron Pipes.—By arresting corrosion the life of iron pipes may be prolonged for a more or less considerable time. For this purpose different substances are applied to the surfaces of pipes, or their surfaces are treated in some special way.

Protective materials take the form of oil paints, enamels, bituminous compositions and glazes, or the surfaces of the pipes may be subjected to a barffing or galvanising process.

Oil Paints are frequently used for treating the surfaces of iron rain-water pipes, gas pipes, etc., but painting only has a limited life and requires periodical renewal. Corrosion is generally very active on the inside surfaces of pipes, and the repainting of these is generally omitted after once they are fixed in position. The inner surfaces of new pipes can be easily painted in the workshop or other suitable place, but if the coating is to be successful the surfaces will require to be properly prepared and all loose scales and sand removed. A

wire brush or similar tool is very suitable for cleansing the inner surfaces of pipes.

A Bituminous Composition, such as Dr. Angus Smith's, is fairly durable, provided the pipes have been properly cleansed and rust is absent when the coating is applied. It is essential, however, that dilute acids are not brought in direct contact with the coating, or the latter will be readily destroyed. To apply the composition, it is raised to a temperature of about 350° F., when the pipes are dipped into the hot solution, and remain submerged until they acquire the same temperature as the solution itself. The pipes are afterwards withdrawn and allowed to drain. Dr. Smith's preparation consists of a mixture of coal-tar and pitch, with a small added quantity of mineral oil. It is largely used for coating cast-iron soil pipes, waste pipes, water pipes, and drains.

Small wrought-iron pipes when laid in the ground are suitably protected by putting them in small wooden channels and surrounding them with pitch.

Glazes are frequently used for coating the inner surfaces of cast-iron soil pipes and drain pipes, and although these may ensure smooth surfaces when the pipes are new, it is very doubtful if this form of protection is worth the price it costs. The glazes commonly applied to iron pipes are easily destroyed by dilute acids, and the cutting of pipes also tends to damage them.

Barfing.—This process may consist of heating the articles to be treated to redness, and by subjecting them to the action of superheated steam. The steam is decomposed, and a thin adherent film of magnetic oxide of iron is formed on the surfaces, and this, for a time, prevents further oxidation taking place. Barfing is suitable for boilers and hot-water pipes.

Galvanising is largely resorted to for the protection of wrought-iron cisterns, cylindrical tanks and wrought-iron pipes. It is effective in some cases, but certain waters readily attack and destroy it. The galvanising of wrought-iron pipes often tends to make them brittle, and great care is necessary when bending the pipes cold. If, however, these pipes are heated to redness, so that bends can be the more

readily made, the zinc coating is destroyed, and the pipes require to be regalvanised. Galvanising is effected by first removing any scales or dirt from the articles to be treated, afterwards they are thoroughly cleaned by submerging in an acid bath, and finally by dipping them into a bath of molten zinc.

Copper.—This metal occurs in the native state in certain places, but only in few in sufficient quantity to work it. The principal locality in which native copper is found is in the district south of Lake Superior. The ores of copper are chiefly found in the form of oxides, carbonates, and sulphides, the latter being the most important. Sulphides are Copper Glance, Copper Pyrites, Erubescite, and Fahl Ore. In this country Cornwall is the only county where large deposits of the ore are found.

Properties of Copper.—It is a tough, very malleable, and ductile metal, and its specific gravity varies from 8.6 to 8.9, its highest value being when in the form of wire. The weight of copper per cubic foot varies from 537 to 555 lb. It is one of the best conductors of heat and electricity. The tensile strength of cast copper is about $8\frac{1}{2}$ tons per sq. inch, and when in the form of wire 26 tons per sq. inch; in the sheet form its tensile strength is approximately 14 tons per sq. inch. It can be forged when either hot or cold, and is softened when heated to redness and suddenly submerged in cold water. Copper often contains impurities such as traces of lead, iron, zinc, tin, and of other metals.

When in the presence of moisture copper is covered with a film of basic carbonate, and when heated to redness it is covered with a film of oxide. It is dissolved by cold nitric acid, but in the absence of air it is not affected by either sulphuric or hydrochloric acid. In the presence of air, however, copper is attacked by weak solutions of these acids.

Coatings for Copper.—To prevent the film of basic carbonate forming on copper-lined sinks and cisterns, and on pipes, etc., their surfaces are frequently tinned. Copper pipes are also electro-plated or lacquered. As the salts of copper are poisonous, plain copper pipes and

cisterns are not suitable for conveying and storing water which is required for human consumption.

Sheet Copper.—Unless specially ordered, sheet copper is not usually made in pieces containing a greater area than 14 sq. feet; it is rolled to various thicknesses to suit the many purposes for which it is required. Common sizes of sheets are, 5 ft. 3 in. by 2 ft. 8 in., 4 ft. by 3 ft. 6 in., and 4 ft. by 2 ft.

Copper Tubes are principally of two kinds: (a) those which are formed with longitudinal seams, and (b) solid drawn or seamless tubes. In the first case the edges which are to be joined are reduced in substance so that they can be overlapped a little, and afterwards they are brought together and brazed. In seamless copper tubes the drawing process tends to make them brittle, and in order to restore ductility it is necessary for the tubes to be annealed. Copper tubes have a very large sphere of usefulness in connection with hot water supplies, and also in connection with hot water and steam heating work.

Tin.—There is only one tin ore, and this is known as Cassiterite or Tinstone. It occurs in the form of an oxide, the chief deposits in this country being confined to Cornwall.

Properties.—Tin has a bright lustre, is very malleable, and melts at about 442° F. It is not very ductile, and the tensile strength of cast tin is only about 2 tons per sq. inch. Its specific gravity is 7.29, and a cubic foot weighs approximately 455 lb. Like lead, tin is not a perfectly elastic metal. When bent, tin makes a crackling noise, and by this means it is easily distinguished from a tin and lead alloy. It is not readily affected by atmospheric air at ordinary temperatures, but it is easily converted into an oxide when heated to redness. Tin is not affected by soft acid waters. Strong hydrochloric acid and hot dilute sulphuric readily dissolve tin, and it is rapidly attacked by nitric acid.

Sheet Block Tin is largely used for covering counter tops in vaults, and for covering drainers to sinks, etc. Tin is specially suited for such purposes on account of its cleanly

appearance and its softness; the latter property prevents it scratching and chipping glass and china ware.

Block Tin Tube.—This is made precisely in the same way as lead pipe, only that a much stronger machine is required on account of tin being harder than lead.

Tin tubes are largely used for spirit and beer pipes, as lead and tin-lined lead pipes are not suited for this purpose.

Zinc does not occur in the native state, and the principal zinc ores are found as oxides, as carbonates, and as sulphides. The last is known by the name of Blende, and is the most abundant and valuable ore. In England zinc is found in Cornwall and in Derbyshire; it is also found at the Isle of Man.

Properties of Zinc.—In colour zinc is bluish-white, and when exposed to moist air it is covered with a thin film of oxide. Its specific gravity when cast is about 7, and a cubic foot weighs about 437 lb. Zinc is a brittle metal when cold, but it is fairly malleable when heated to the temperature of boiling water. At 300° F. it can be rolled into sheets, but when its temperature exceeds about 350° F. it again becomes brittle. Its melting point is approximately 770° F., and at a red heat it boils. Zinc is readily attacked by an acid-laden atmosphere, and dissolves readily in most acids. It always contains more or less impurity, such as iron, lead, and other metals.

Sheet Zinc.—The sizes of the sheets into which zinc is rolled vary in length from 7 to 10 feet, but all sheets have a uniform width of 3 feet. The life of zinc is comparatively short in large manufacturing centres, and when laid on roofs under otherwise favourable circumstances it will only last about twenty years. In country districts it has a much longer life, provided it is properly laid and the area of one piece is not too large.

In the *ingot form* zinc is known as spelter.

Alloys.—An alloy may be defined as a mixture of different metals where their union has been effected by fusion. In an alloy the metals are not in proportions which produce a definite chemical compound, for upon cooling whilst in the

molten state it is found that the metals composing the alloy tend to separate and arrange themselves in different layers. The tendency for the constituents of an alloy to separate themselves is very noticeable in plumbers' solder, and before a plumber takes a ladleful of solder from the pot to make a joint, he first stirs it so as to thoroughly mix the lead and tin.

An alloy, however, is not a mere mechanical mixture, which tends to separate into its constituent parts under favourable conditions, and although such separation takes place to a considerable extent, it will be found that the layers are not pure metal, but that each has alloyed with it a certain amount of another metal.

Properties.—The properties of alloys usually differ considerably from those of the constituent metals, alloys being usually harder and more brittle. Their melting points are frequently less than those of their most fusible constituents, and their tensile strengths and ductility may be either greater or less than those of any constituent metal.

The chief alloys (excepting solders) with which the plumber is principally concerned, are the Copper-Tin alloys, and the Copper-Zinc alloys. From the former are made the best qualities of water and steam fittings, whilst fittings of a lower grade are produced from the latter alloys.

Gun-metal belongs to the copper-tin series. A strong alloy, and one which will withstand the action of acid waters, is produced by a mixture of 90 per cent. copper and ten per cent. tin.

An inferior *gun-metal* to the above is made by combining 85 per cent. copper, 10 per cent. tin, and 5 per cent. lead.

For spindles in connection with valves, a harder gun-metal can be produced by alloying with the copper and tin a small amount of phosphorus.

Brass.—This alloy is obtained by a mixture of copper and zinc. Brass may be either yellow or white, the colouring depending upon the percentage of copper which enters into its composition. When the amount of copper is less than 45 per cent. the colour is white. The proportions of copper and

zinc vary considerably, and the amount of copper may be anything from 40 to 80 per cent.

Ordinary yellow brass contains 67 per cent. of copper and 33 per cent. of zinc. Many of the inferior brasses contain more or less lead. Common brass is unsuited for water fittings when the latter are used for sea-water and soft acid waters.

The action of sea-water on copper-zinc alloys can be minimised to a great extent by including in the mixtures 1 per cent. of tin. Brass which contains iron and lead is subjected to more or less rapid corrosion when in contact with sea-water.

Compositions of a few other alloys are as follows:—

Red Brass.—90 per cent. copper and 10 per cent. zinc.

Muntz Metal.—60 per cent. copper and 40 per cent. zinc.

Aluminium Bronze.—90 to 97½ per cent. copper and 2 to 10 per cent. aluminium.

German Silver.—50 per cent. copper, 25 per cent. zinc, and 25 per cent. nickel.

Soft Gun-metal.—95 per cent. copper and 5 per cent. tin.

The greatest tensile strength of a copper-tin alloy is approximately 17 tons per sq. inch, the relative proportions of copper and tin being roughly 88 per cent. of the former to 12 per cent. of the latter metal. A greater or less percentage of tin diminishes the tensile strength of the alloy.

In the copper-zinc alloys the tensile strength reaches a maximum of approximately 14½ tons per sq. inch, when the copper and zinc are in the proportion of 80 per cent. of the former to 20 per cent. of the latter; the tensile strength diminishes with either a greater or smaller amount of zinc.

Sanitary Pottery.—Although it is often thought that the materials for the production of porcelain goods are found in the neighbourhood of the potteries, such is not the case. The principal materials employed in porcelain manufacture are calcined bone, china clay, blue or ball clay, flints, and partially decomposed granites. China clay and granites are obtained from Cornwall; ball clay from Dorset and Devonshire, and the flints are obtained from Newhaven and Dieppe. Each

material has its own special property, such as for imparting fineness, plasticity, and strength to the clay, or for controlling the rate of contraction when firing the clay.

To produce porcelain goods from the crude materials to the finished state takes several weeks, and much skill and care are required as they pass through the different stages of manufacture. The first stage towards the preparation of the clay is the separate treatment of each ingredient, which is ground in water so as to bring it into a suitable state for mixing. Before the flints can be ground they are first calcined. In the "slip house" the ingredients are measured out and mixed in the correct proportions, and any shade or colour can be obtained by introducing into the liquid "slip" stains and metallic oxides. The "slip" now requires to be brought into the plastic state, and this is done by pumping it into clay presses, where the surplus water is removed. After leaving the presses, the plastic clay is passed into the pug mill, from which it issues of uniform consistency and ready for the potter to mould. The clay is pressed into the moulds so as to form one homogeneous mass. A mould is made up of a number of parts, the exact number depending upon the kind and shape of fitting required, and great care is essential in joining the separate parts so as to avoid cracks appearing at the joints when the goods are being fired. Before the goods are ready for the oven they first must be thoroughly dried. The firing process is performed by placing the goods in "saggars," which are fireclay receptacles of different sizes and shapes and of about 1 inch in thickness; the "saggars" afford protection from the intense heat of the fires, and subject their contents to a more nearly uniform temperature.

The first firing process is carried out in the "Bisque" ovens or kilns, which are of circular or other suitable form, the firing being done from a number of points. The "saggars" containing the articles to be fired are built up in the ovens, and when the latter are fully charged the doorways are built up and the fires lighted. By means of dampers the draught is regulated and a gentle heat is maintained for about 30 hours; the temperature is then

raised to about 2000° F. and maintained for a further 24 hours or so.

The goods when removed from the bisque ovens are in a partially baked and semi-porous state, and whilst in this condition any minor defects can be rectified, the spoiled or damaged goods being thrown aside. If the articles are to receive any form of decoration this is often effected at this stage, but if the goods only require a plain finish they are taken to the dipping house to be glazed.

One mode of dipping consists of passing the things through the dipping-tub, in which glaze is suspended in water, the ware absorbing a sufficient quantity of the glaze to form a coating over its surfaces. Before the glaze can be fired all moisture requires to be expelled by gradually drying the goods.

The treated articles are placed in "saggars" as before, whilst to protect the glazed surfaces during the firing process, and to prevent their adhering to the "saggars," the goods are supported on studs. The ovens in which the glazing is completed are known as "Glost" ovens; they are similar to the "Bisque" ovens, excepting that they are sometimes a little smaller and are heated to a higher temperature. The firing takes about 24 hours, and the temperature is quickly raised in order to fuse the glaze and to produce a smooth and even surface. The ovens are then allowed to cool for about two days, when the contents are withdrawn.

Fireclay and Brown Earthenware Goods are made from coarser materials, such as the fireclays which overlies the coal measures. Different qualities of clays are also produced by the mixing of the coarser with the finer kinds along with other ingredients.

Earthenware Drain Pipes.—There are two principal classes of drain pipes, (a) fireclay pipes and (b) stoneware pipes. The clay for the former is the more abundant and the more widely distributed, while that for the latter is chiefly confined to the counties of Dorset and Devon. Fireclays are rather coarse grained, and the pipes made from these clays depend principally for their water-tightness

upon the quality and thoroughness of the glazing. On the other hand, the clays from which stoneware pipes are made are very closely grained and are denser than fireclays. Stoneware pipes are much superior to fireclay pipes, and the former are especially suited for resisting the action of acids.

In England earthenware pipes of 12 inches diameter and less are made usually in lengths not exceeding 2 feet; larger sizes being generally 3 feet long. In Scotland 3 feet lengths are general for all sizes of earthenware drain pipes which exceed 3 inches diameter.

The thickness of stoneware pipes is usually equal to about $\frac{1}{10}$ their diameters, but fireclay pipes to be of equal strength would require to be a little thicker than this. The relative strength of fireclay and stoneware is stated to be in the ratio of 10 to 12.

Earthenware pipes are generally salt glazed.

Concrete Tubes are sometimes used for drainage work, and these are quite smooth, true in section, perfectly straight, and practically non-absorbent. They are made in steel moulds, and the concrete tubes may be reinforced with metal rods when extra strength is desired. In price, concrete tubes compare favourably with earthenware pipes, and for large sizes of pipes the concrete form has the advantage.

CHAPTER II

ROOF WORK

Metal Coverings.—The principal sheet metals which are used for roof work are lead, copper, and zinc. For general work sheet lead possesses important advantages, so that its displacement by other materials is confined chiefly to special cases.

Lead has the advantage of adaptability in a marked degree, as it can be readily worked into shapes to fit almost any position; it is also a very durable material, and its cost is not excessive. The principal drawback of lead is its weight.

Copper possesses the advantage of lightness when compared with lead, and it can be rolled and used in much thinner sheets. Copper is a very durable metal, and is specially suited for covering domes, turrets, and similar structures.

Zinc may be used in rural districts with good results, provided it is properly fixed, and removed from situations where large volumes of sulphurous acid gas are emitted. For towns and manufacturing districts zinc is unsuitable on account of the amount of sulphurous and other acids which are always present in the atmosphere of such localities. The advantages possessed by zinc are lightness and cheapness.

When executing sheet leadwork the points which require consideration are as follows:—1. That the area of one piece of lead be not larger than where movement due to changes of temperature can readily take place. 2. That the lead be fixed in such a manner as will prevent its sliding or tearing from its original situation by its own weight, or being removed by the force of the wind. 3. That water be prevented from gaining access to the woodwork

supporting the lead by the former rising between the laps or passings. 4. That all woodwork supporting lead be properly laid to the required falls, and that before the leadwork is placed in position all projecting nails be punched and the woodwork swept clear of dirt.

Narrow boards should be used for gutters, lead flats, etc., and these should be laid in the direction the water will flow.

Returning to the first point, lead, if laid in very large pieces, is unable to move freely on account of its weight and its softness. Thus, when a piece of lead expands or contracts, unless it can bodily move, stresses are concentrated at one or more points; the result is that the lead begins to buckle, and is eventually cracked or torn. With regard to the maximum area of one piece of lead, this should not, as a rule, exceed 20 superficial feet. Discretion of course requires to be exercised, according to the purpose for which the lead is required and the position in which it is to be fixed. It is obvious that when lead-work is laid in exposed situations it should be in smaller pieces than when in sheltered places.

The second point refers to the methods of securing lead-work in position, but these will be dealt with as the various sections of roof work receive consideration.

With regard to the third point, water may gain access to, and bring about the decay of, the timbers in the following ways:—

(a) By capillary attraction due to accumulation of dirt at gutter drips, or by drips being too shallow. (b) By driving wind and rain, the latter getting under the lead when the drips are shallow, or at the joints when there is insufficient overlap. (c) By defective workmanship.

LEAD FLATS.

Lead Flats usually include all lead covered surfaces which can be walked upon. On flats the leadwork is arranged in the form of bays by either introducing solid or hollow rolls. *Solid roll* work possesses the advantage of not being so readily disfigured when walked upon as *hollow roll* work, and the former can be more speedily executed than the latter. The

chief drawback of *solid roll* work is the difficulty of securing the lead on inclined surfaces so as to prevent its sliding or crawling down, unless soldered dots are resorted to. As ordinarily carried out, *solid roll work* only permits of the lead bays being secured across their top edges and along their undercloaks.

Hollow rolls permit of the lead being fastened by means of copper ties on both sides of a bay, and thus very substantial fixings are obtained. In exposed situations the leadwork is also less liable to be displaced by high winds, as no free edges are left (except under special circumstances) at the sides of the rolls. Wood cores are also dispensed with.

The chief drawback of *hollow rolls* is their liability to disfiguration by being crushed when walked upon, and by materials falling upon them during the erection of buildings. In England *solid roll* work is generally adopted, whilst in Scotland *hollow roll* work is predominant.

Fig. 3 shows a portion of a lead flat which is 17 feet in width; the flat on three sides is supposed to be bounded with high walls, whilst a low parapet wall is represented in front. As the water must drain in the case shown towards the front wall, where a gutter is formed, a drip will be necessary to divide the flat in order to reduce the bays to a suitable length. The left side S, Fig. 3, shows how solid rolls are arranged, whilst the right side H indicates how hollow rolls are generally arranged where the drip or step dividing the flat is not more than 3 inches deep. When arranging the bays for a flat, their widths should be governed to a great extent by the widths of the sheets of lead, so as to avoid producing unnecessary scrap. As a rule the width of the bays should not exceed 2 feet when their length is about 8 feet. If the bays are short, their width, of course, can be increased, but the width decided upon should permit of the lead being cut to advantage.

Approximately a total width of 9 inches of lead is required for the under and overcloaks of solid rolls, and about 7 inches for hollow rolls. Thus if a sheet of lead has a width of 7 ft. 9 in., this will cut into three strips, each having a width of 2 ft. 7 in. Supposing hollow rolls were used, then

$2' 7'' - 7'' = 2$ ft., which would be a suitable width for the bays when of moderate length. For solid rolls we have $2' 7'' - 9'' = 1$ ft. 10 in. as the width suitable for the bays.

Solid Rolls.—A common method of treating solid rolls is shown in Fig. 4. The thick edge of the undercloak should be reduced with a shave-hook or other tool, or a crease will be formed in the overcloak. The overcloak is shown finished

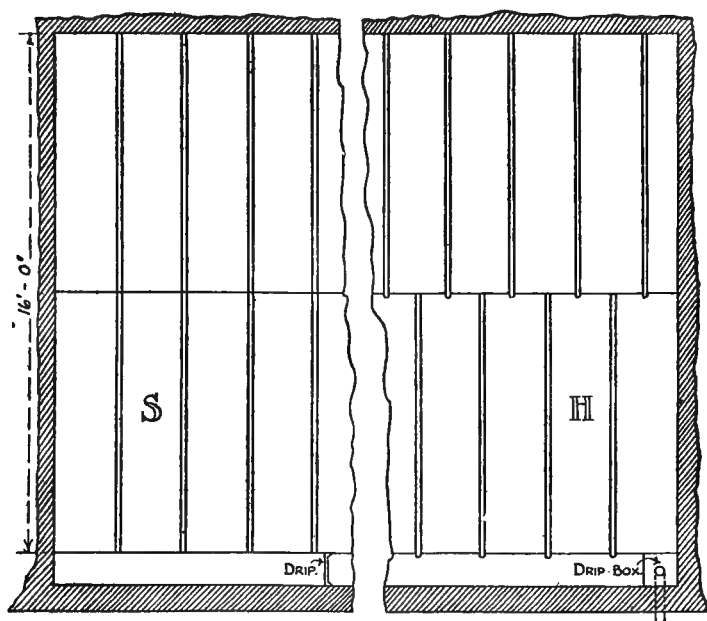


FIG. 3.—Plan of lead flat showing arrangement of solid and hollow rolls.

off with a width of about one inch on the flat; the object of the lap is to stiffen the overcloak at the angle, and also to prevent its slackening to a great extent on the roll. To hold the lead in position the rolls require to be well shaped and well undercut, as indicated in Fig. 4. For general work a wood roll should not be less than 2 inches high, its widest part not smaller than $1\frac{3}{4}$ inches, whilst the bottom should not exceed 1 inch in width.

Instead of the overcloak being treated as in Fig. 4, some-

times the lap on the flat is omitted, and the edge of the overcloak is finished off on the side of the roll, about one quarter of an inch above the flat. It is supposed in the latter case that moisture is prevented from gaining access by capillary attraction to the timbers which support the lead. The possibility of leakage by this means, however, is often overrated, for where rolls have a minimum height of 2 inches it is usually impossible, under ordinary circumstances, for capillary attraction to occur. Finishing off the overcloak on the side of a roll possesses the disadvantage of allowing the lead to slacken on it, either when the lead is walked upon or by the action of the weather.

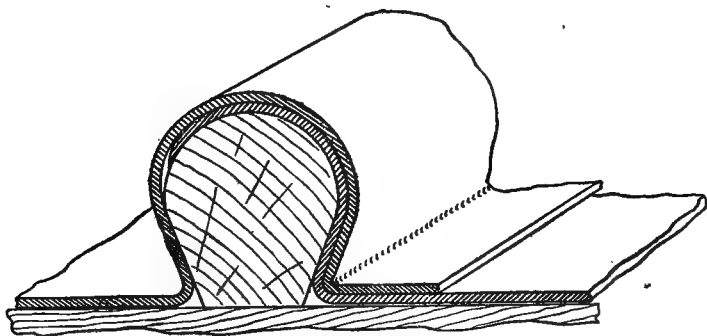


FIG. 4.—Section of solid roll showing leadwork.

It is desirable when laying lead on flats that the wood rolls, after being fitted by the carpenter, be finally secured in position by the plumber as the work of lead laying proceeds.

Laying Lead.—Before a piece of lead for a flat is laid in its place, assuming the necessary setting up and bossing in connection with it has been done, the large flat surface should be raised by either striking it with the hand or with a soft wood dresser. The lead is then laid in position, and the wood roll fixed against the upstand which represents the undercloak, and the roll made secure by nailing it down. The undercloak lead is easily pressed over the roll with the hand, and finished off with a soft wood dresser. For setting in the lead at the sides of the rolls, a proper setting-in dresser

should be used, or an ordinary beech dresser which has been cut to suit the shape of the rolls may be used instead.

To get the overcloak tight on the roll often presents a little difficulty to the young plumber, but this can be accomplished by carefully bending the upstand well over the roll for the whole of its length; the lead can then be made to take the shape of the roll by partially setting it in along the free edge with a large hammer and with a spare piece of wood roll, which has had any sharp edges rounded off. The overcloak can afterwards be drawn tightly over the roll, by setting in the sides with a blunt-edged dresser, and finishing it off with an ordinary setting-in dresser or other suitable tool.

To keep lead free from tool marks the flat dresser should be used as sparingly as possible, and if the rolls are treated in the manner described they will present a smart and clean appearance. Large flat surfaces can be left free from marks by using a planisher (which is made from a piece of scrap lead) in lieu of a dresser.

Fig. 5 shows how finished solid roll work for a flat appears where a step is necessary to reduce the length of the bays. Overcloaks should be arranged that their free edges are on the side most sheltered from driving rain. The step in a flat must be higher, of course, than the rolls, in order to prevent water following under the laps at the rolls where the latter butt against the step.

If, however, it is found in a flat that the height of a step and the rolls are about the same, and that no great departure from this can be made, the ends of the rolls in the immediate neighbourhood of the step should have their height reduced so as to come half an inch or so below it.

Roll Ends.—The ends of solid rolls should terminate flush with the edges of flats, and not be cut a little short as is often done. With regard to the shape of the ends, it is unimportant whether they are cut off square or cut sloping. Before working down a roll end, however, it is essential that all sharp edges are removed. Roll ends A, Fig. 5, are not difficult to work down, but care requires to be taken so that the lead is not unnecessarily reduced or split at the sides by too much setting-in. The overcloak B, Fig. 5, is more difficult to work

on account of the lead being bossed round the lower roll, and also finished off with about an inch lap on the flat surface. In working the overlap B, Fig. 5, the left side of the roll is first dealt with, and that part should be well held down to prevent its rising whilst the right side is being bossed into shape. The upper end of roll, as at C, Fig. 5, can readily be dealt with by first pressing down part of the upstand along

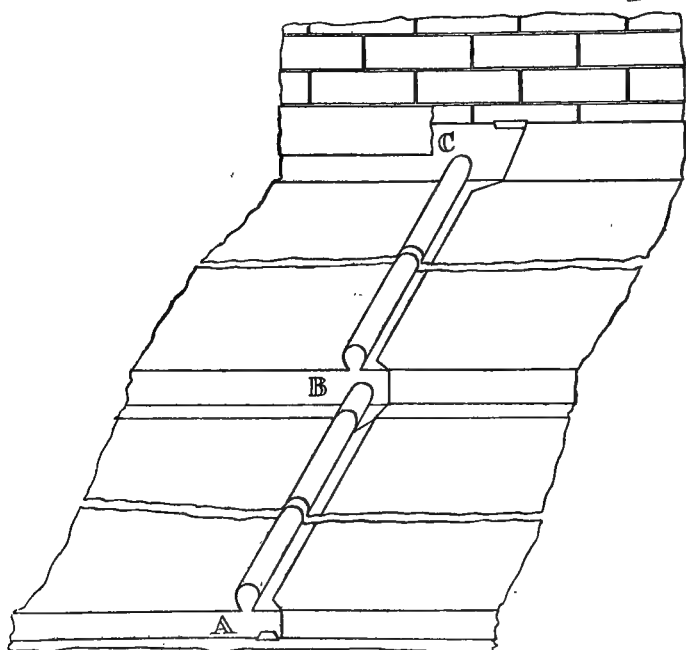


FIG. 5.—General view of solid roll work.

the top of the bay, so as to enable the overcloak at C to be bent round the roll. By careful working, the lead is readily driven into the corner so as to take the form required.

For securing the bays the undercloaks are copper nailed to the wood rolls, but this method of fastening is inadequate to prevent the bays creeping down unless the flats have little or no pitch.

Soldered Dots.—When lead is laid on a surface with a moderate pitch, and where solid rolls are used, *soldered dots*

are frequently adopted as fixings. For a flat with a moderate pitch usually two dots are made on each bay, these being located near the lower edge. Soldered dots may either be flush wiped or raised, both forms being shown in Fig. 6. The raised form is represented by A, and the flush one by B;

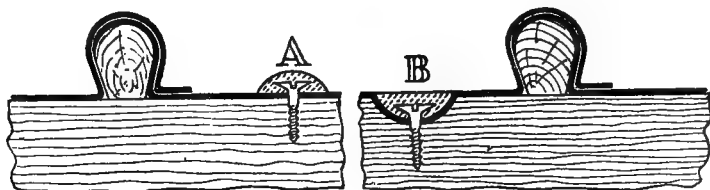


FIG. 6.—Raised and flush soldered dots on flats.

and in each case the lead is held secure by means of strong screws, which are driven through it into the woodwork beneath. To make the solder adhere to the screws they are first tinned. When making soldered dots, the heads of the screws should be left raised a little above the lead in order

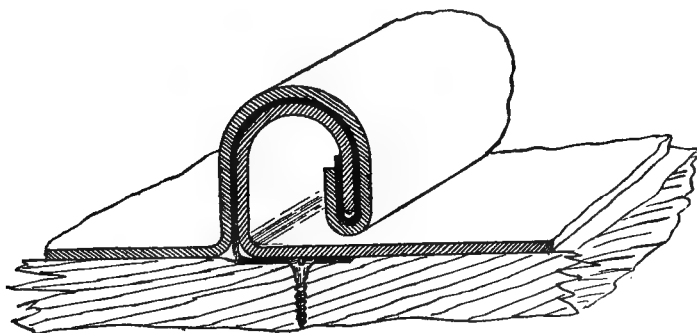


FIG. 7.—Hollow roll with copper tie.

that the solder will flow underneath, and so permit the whole to be properly sweated together. Occasionally tinned washers are used to present a larger surface to the solder, but if strong screws are used and their heads completely tinned, then the washers may be discarded. The solder over the screws need not be more than about $2\frac{1}{4}$ inches diameter.

The principal drawback of soldered dots is that they hold

the lead too rigid, and after a time it is found that, where they support heavy pieces of lead, the screws work their way up and through the solder, owing to the thrust and pull which are concentrated upon them. Of course where dots are well made, suitably placed, and the pieces of lead not unduly large, it may take many years before the screws work out above the surface of the solder.

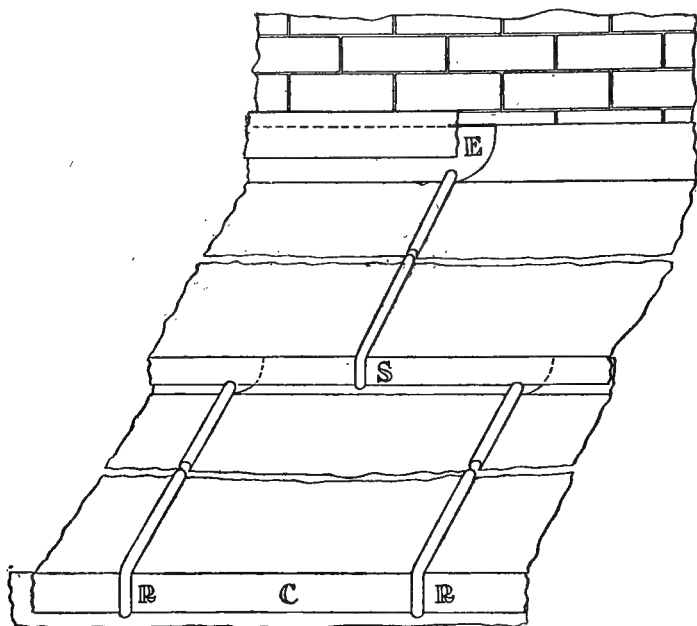


FIG. 8.—View of hollow roll work for lead flats.

Hollow Rolls are much superior to solid rolls for sloping surfaces, as these permit of the leadwork being made secure without resorting to soldered dots. These rolls are not made so large as solid ones, their height as a rule not exceeding $1\frac{1}{2}$ inches; the thickness of the lead affects the size of hollow rolls to a certain extent.

In Fig. 7 is shown a section of a hollow roll with copper tie; the latter is screwed to the woodwork, and the free end is turned between the under and overcloaks. Copper ties are fixed about 2 feet apart, and are from

2 to 3 inches in width. On account of the under and overcloaks being wholly in contact with each other one bay cannot slip from another. The leadwork as a whole is prevented from bodily giving way by the copper ties, which are provided at regular intervals throughout the whole length of the rolls.

A plan of hollow roll work has already been shown in Fig. 3, whilst Fig. 8 gives a part view showing how the rolls may be treated where a drip or step occurs in a flat.

Where the curb C, as in Fig. 8, is a plain one, the roll ends R are usually finished off by turning them down as shown. If a curb is in an exposed situation it is advisable to add a nosing piece, over which the lead is turned, as at A, Fig. 9. Occasionally roll ends are treated as at B, Fig. 9, but in the latter case much more labour is involved in turning the roll on the curb or vertical surface. As a rule the method denoted by B, Fig. 9, of forming the end of a roll is unnecessary, and not worth the extra labour and cost it entails.

When a step or drip occurs, as at S, Fig. 8, it is treated differently to that where solid rolls are used. In hollow roll work the under and overcloaks of steps are "clinked" or

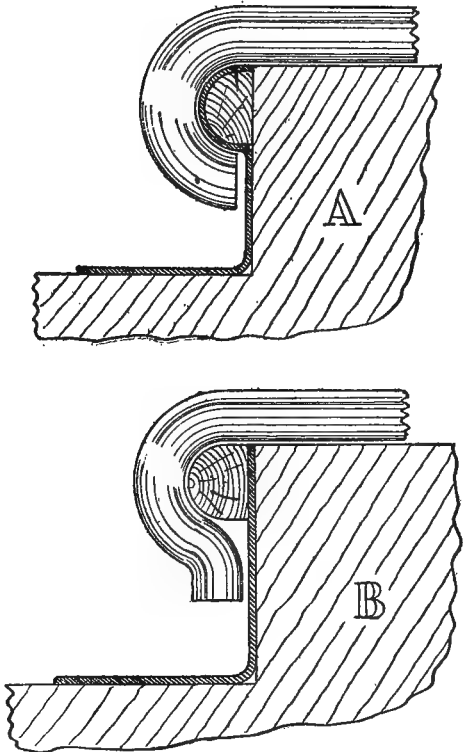


FIG. 9.—Methods of finishing the ends of hollow rolls.

"welted" together, as at C, Fig. 10. In order to double the lead under at the roll end of the upper bay, the turned end S, Fig. 8, is cut to its finished length; the lead forming the overlap is then free at the end of the roll, and will admit of its being doubled under and into position as partly shown by D, Fig. 10.

The upper end of the hollow roll E, Fig. 8, or one in a similar situation can be treated in different ways, but the method shown is the simplest and has the best appearance. Another method of treating the upper end is to form the

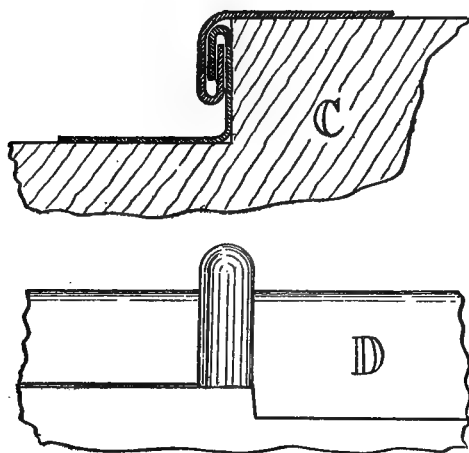


FIG. 10.

roll on, and to the top of the upstand. A third method is to form a clink or welt at the upstand.

The enlarged detail A, Fig. 11, shows how the undercloak at the upper end of a hollow roll may be prepared, whilst B of the same Fig. denotes the overcloak in a finished state.

It is essential when

the ends are treated as in Fig. 11 that the lead of the overcloak is worked well down and into the corner at *p*; unless this is done a leakage may occur at that point when there is a heavy shower of driving rain. The undercloak A, Fig. 11, is prepared by first bossing up the corner about $1\frac{1}{4}$ inches high in the ordinary way, and then by forming the lead so as to enable the undercloak to be turned over inwards as shown. As regards the overcloak, that is worked into position in a similar manner to that for solid rolls, excepting that from point *p*, Fig. 11, the free edge of the overcloak is doubled under to form part of the roll. From the particulars supplied it will be obvious why hollow and

solid rolls differ in their arrangement (see Figs. 5 and 8) when the platforms are wide.

Intersecting Rolls.—A part plan showing how the lead-work is arranged where solid intersecting rolls are used is given in Fig. 12. The numbers on the bays indicate the order in which they may be laid. Where the intersections occur some of the underlaps will require to be cut out so as to avoid giving the rolls a clumsy or bulged appearance at those points. The method of trimming the undercloaks is shown by bay No. 12; at the top of the centre roll part of the undercloak is represented as cut away, and the free edge should be well reduced by a rasp. Bay No. 1, Fig. 12, it will be observed, has an overcloak on each side; this is

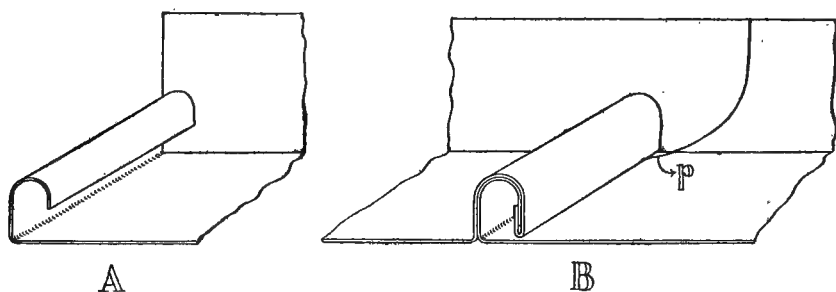


FIG. 11.—Formation of the upper ends of hollow rolls.

owing to the overcloaks of the side bays being turned in the same direction.

The allowance of lead to cover the intersections requires to be liberal, otherwise there may be difficulty in obtaining adequate laps and preventing the lead from being torn. When working an overcloak round the intersections, after any particular part is once in position it should be firmly held there, to prevent its being withdrawn when bossing at another point. After the rolls are covered the overcloaks should be made secure by copper ties which have been previously introduced. For exposed situations the ties should be about $2\frac{1}{2}$ inches wide, and fixed at intervals not exceeding 2 feet.

In hollow roll work different methods are adopted for

dealing with intersections, some involving much more labour than others to execute. For large flats, wood cores are generally used for the centre and diagonal rolls, as at D, Fig. 13. Wood rolls in these positions simplify the work and allow the lead to be more quickly laid. No wood cores are used for small flats with intersecting rolls, as no special difficulties are presented as in larger flats where the rolls are numerous.

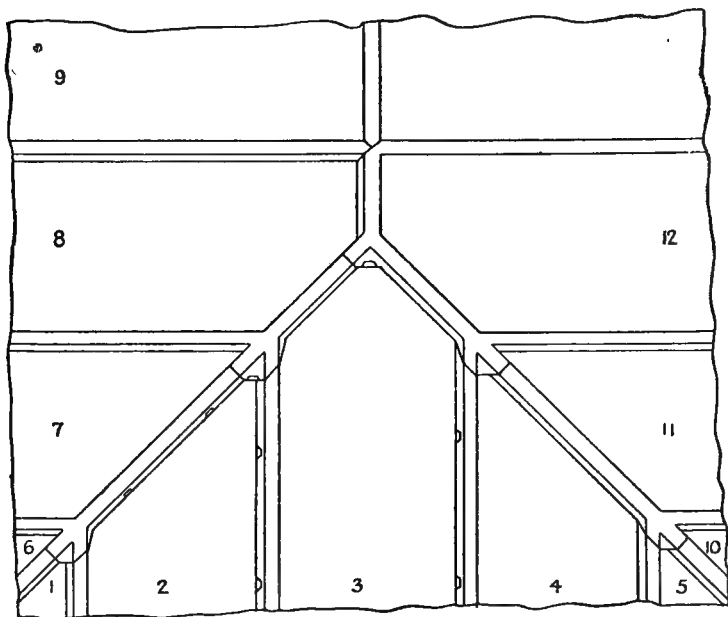


FIG. 12.—Plan showing intersecting solid roll work.

In Fig. 13 two methods are shown of dealing with the intersections of the rolls; in each case wood cores are used for the centre and diagonal rolls, and the upstands of opposite bays are turned on these cores, the free edges of the lead meeting at the top, as on the left diagonal roll and on the centre roll Fig. 13. Separate capping pieces are required for the wood rolls, and the right diagonal one shows a capping piece in position with the lead worked round the intersections and secured in position with copper ties. With

regard to the hollow intermediate rolls, they may be joined with the wood cores by treating their ends in a similar way to that shown in Fig. 11; whilst the free edges of the overcloak at an intersection may be trimmed, as in the left diagonal roll Fig. 13.

The other method of treating the ends of hollow rolls, where the latter intersect with the wood cores, is illustrated on plan by *cf*, Fig. 13. In this case the ends of the

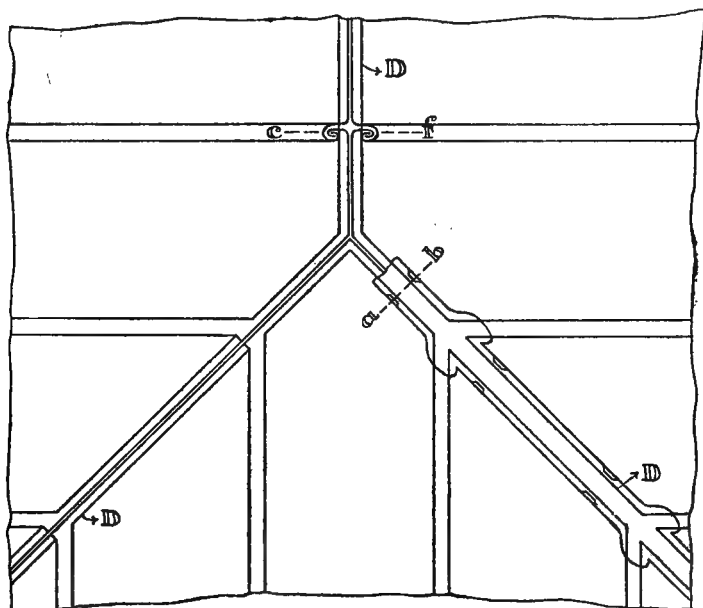


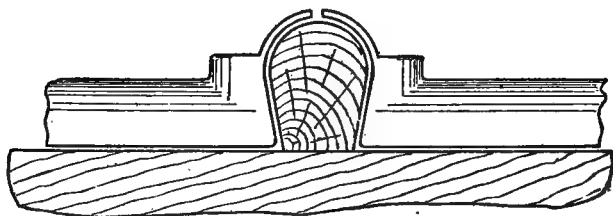
FIG. 13.—Plan showing intersecting hollow roll work.

hollow rolls are turned upwards against the centre core, as shown by the enlarged detail A, Fig. 14. Separate capping pieces, as before, are required for the wood cores, but the turned ends of the hollow rolls present a rather clumsy appearance at the intersections. Fig. 14, B, gives a section showing how the ties are fixed to hold the capping pieces in position. For this class of work the ties should be fixed about 18 inches apart.

In Fig. 13 the bays may be laid in the same sequence

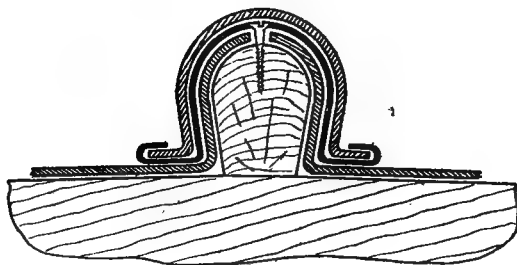
as in the previous figure, but the order may be varied if desired, as this system of laying lead allows plenty of scope so far as the arrangement of the bays is concerned.

It is sometimes thought that hollow roll work is more subject to leakage than when solid rolls are used; this



A

Hollow rolls turned against wood core.



B

Copper tie and capping flashing.

FIG. 14.

depends, however, upon the manner in which the work is carried out. If hollow roll work is indifferently executed, leakages at some of the corners will most likely occur; on the other hand, if the work is properly done, and the rolls not unduly trampled upon, hollow rolls provide one of the strongest and best means for securing lead, both for large horizontal and moderately pitched surfaces.

LEAD GUTTERS

Lead-lined gutters, owing to their width, require little fall, and an inclination of 1 in 108, or 1 inch in 9 feet, is ample provided that suitable drips are made. If practicable, a length of gutter between two drips should not greatly exceed 9 feet, and for exposed situations shorter lengths are desirable.

Box Gutters which have a uniform width need not be more than 10 inches wide unless they are formed between two pitched roofs. A little extra width under the latter circumstances is advantageous, as there is less danger of damaging the eaves when walking in the gutters.

Tapering Gutters.—Ordinary *parapet* wall gutters which vary in width do not usually require their narrow ends being more than 9 inches wide; this width may also be reduced a little for special cases.

Care should be exercised when setting out gutters so as to keep the area of the leadwork within reasonable limits.

If a tapering gutter is long, with the fall in one direction, its width rapidly increases; this is especially the case where the

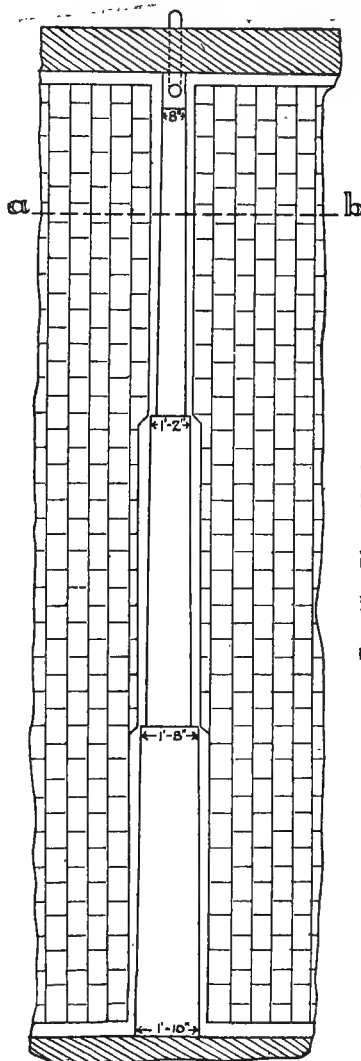


FIG. 15.—Plan of lead gutter.

roofs have a small pitch. Where possible, long, tapering gutters should be arranged in short sections, by locating drip-boxes at suitable points; when this is done the width of gutters can be kept within reasonable bounds.

As a rule the height of drips should not be less than 2 inches, and in some districts a minimum height of $2\frac{1}{2}$ inches is adopted. Of course very deep drips appreciably add to the width of tapering gutters.

Fig. 15 gives a plan of a gutter which is located between two pitched slated roofs; its total length between the two walls is 28 feet, and this allows it to be divided into three lengths, each 9 feet between drips, and with a drip-box

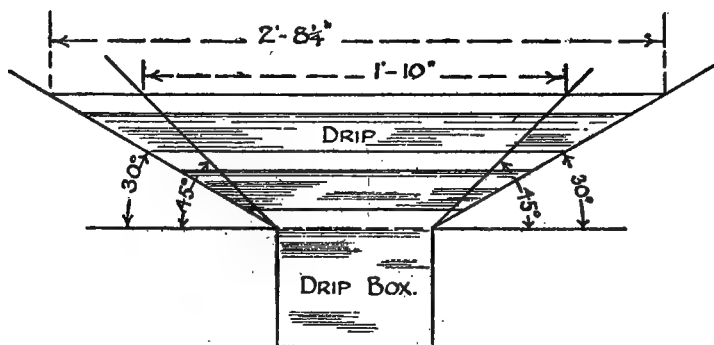


FIG. 16.—Drawing for ascertaining width of gutter bottom at any point.

1 foot in length. Assuming that each roof has a pitch of 45° , the narrow end of gutter 8 inches wide, the drips 2 inches deep, and that each 9 feet length has a fall of 1 inch, then under these conditions the width of the gutter bottom, Fig. 15, at the wide end would work out at 1 ft. 10 inches; and the widths of the gutter bottom at the top of the intermediate drips would be 1 ft. 2 in. and 1 ft. 8 in. respectively.

Supposing, now, that each roof in Fig. 15 had had a pitch of 30° instead of 45° , the remaining particulars as before, the widest end of the gutter bottom would have been 2 ft. $8\frac{1}{4}$ in., and the widths at the top of the intermediate drips about 1 ft. $6\frac{1}{4}$ in. and 2 ft. $4\frac{3}{4}$ in. These values

clearly indicate the influence that low pitched roofs have on the widths of tapering gutters.

A common method of ascertaining the width of any part of a gutter prior to its formation is indicated by Fig. 16, which shows the widths at different points of the gutter under consideration. In practice, the sketches are made to a large scale, or, better still, full size, so that the dimensions can be easily measured off with an ordinary rule.

When a gutter gets very wide, the width of the lead to cover it may be broken up by introducing one or more rolls.

A section through *ab*, Fig. 15, is given in Fig. 17. The distance the sheet lead should turn over the fillets in order

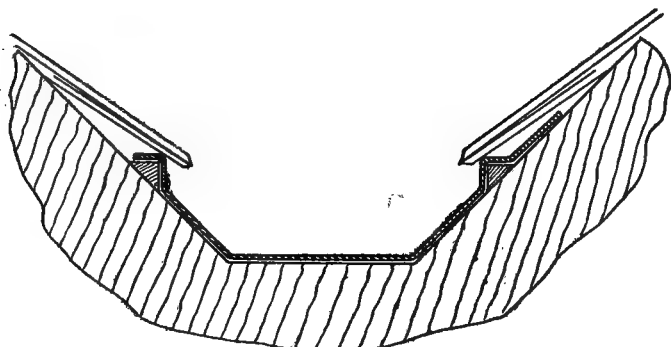


FIG. 17.—Cross section of lead gutter between two pitched roofs.

to avoid water following back under the slates and getting behind the leadwork, chiefly depends upon the pitch of the roof. For quick pitched roofs it is only necessary to turn the lead about 1 inch over the fillet, as on the left side of Fig. 17. Slow pitched roofs, on the other hand, should have the lead carried right over the fillet, and about 3 inches up the roof, as shown on the right side of Fig. 15.

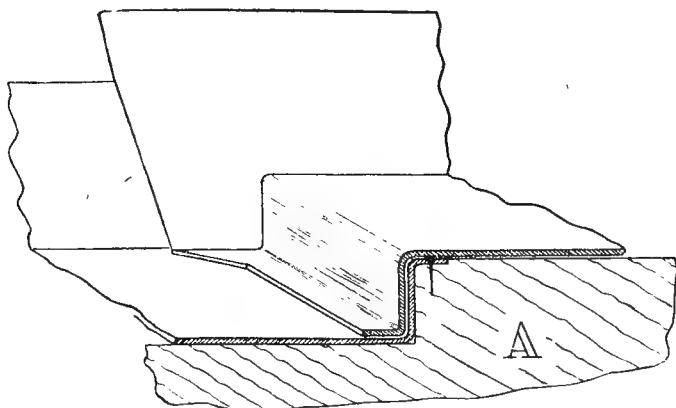
Drips.—There are two principal types of drips, viz.: the square drip and the splayed drip, and these are shown in Fig. 18. The lead is a little easier to work down when the drip is splayed, and naturally some plumbers prefer it. Either form of drip is satisfactory when deep enough, and where the lead is properly worked over it.

The chief advantage of the square drip is that the lead is more rigidly held in position than in the splayed form, but many plumbers make a poor job of square drips by letting the overcloaks rise above the wood bearing.

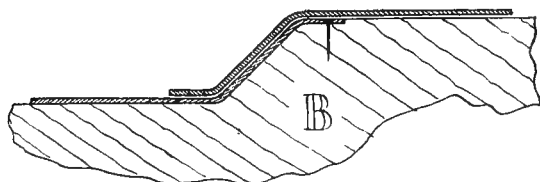
Drips are easily formed if the upstand lead, or that which lies on the roof surface, is first bent down and inwards; this enables the end of the gutter to be bent down to take the shape of the drip, when the lead can be readily bossed to take its correct form.

Sharp "chase" or "set" wedges should not be used when forming drips, as these unnecessarily reduce the lead where strength is most required. At A and B, Fig. 18, the overcloaks of the drips are shown finished off on the sole of the lower lengths of gutter; this form of finish is desirable for drips which do not exceed 2 inches in depth, as it strengthens the lead at the angle and keeps it in position. Occasionally the overlap of drips is cut off about $\frac{1}{4}$ inch above the lower angle, as at C, Fig. 18. The object of treating the drips in the latter way is intended to prevent water rising by capillary attraction between their under and overlaps, and so gaining access to the woodwork beneath. This source of leakage, however, is often greatly exaggerated in gutters, and it is very doubtful if the trimming of 2 inch drips, as at C, Fig. 18, serves in a small degree the purpose it is intended. The height to which water will rise by capillary attraction between two surfaces depends upon their distance apart. After gutters have been laid for a short time the surfaces at the drips, which were originally dressed close together, get a little apart, and the separation of the surfaces by natural agencies prevents capillary attraction from taking place in drips of moderate depth. Even in drips which have a depth of $1\frac{1}{2}$ inches and less, and where the overlaps are cut clear of their lower angles, the risk of leakage due to driving rain is often much greater than that which is likely to occur from capillarity. Capillary grooves are often shown and suggested for small drips, but such grooves could only be cut in fairly deep drips, and in such cases their adoption would serve no useful purpose. For drips over 2 inches deep

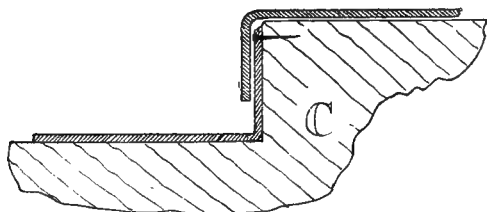
they are often formed as at C, Fig. 18, where the under lap is carried to the top of the drip and not over it as in A



Vertical drip with overcloak finished on sole of lower length.



Splayed finished on sole of lower length.



Vertical drip with overcloak finished clear of lower angle.

FIG. 18.

and B of the same Fig. Where deep drips are wide, and there is danger of the overlaps being displaced, they can be treated in a similar manner to that shown at C, Fig. 10.

Box Gutters.—An ordinary form of box gutter is given

in Fig. 19, where the bottom for the whole length of the gutter is of uniform width; the method of treating the leadwork requires no special comment, as the work is practically the same as in the gutter already described. The upstand lead y against the wall is generally about 6 inches, but in some cases it may be an inch less than that. The depth x , Fig. 19, will necessarily vary at different points, but that can be ascertained either by calculation or by means of a sketch which allows for the slope of the gutter and depth of drips. At the higher end of a box gutter the depth x , Fig. 19, should not be less than 2 inches.

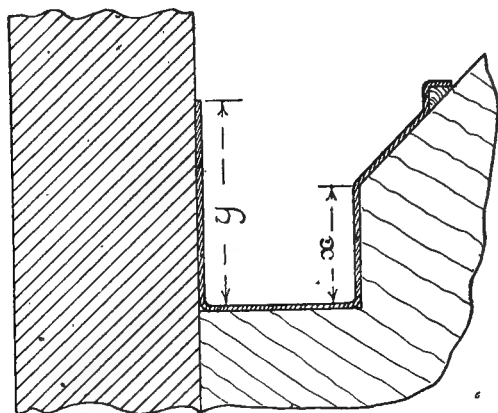


FIG. 19.—Box gutter.

Valley Gutters.—Fig. 20 shows a valley gutter or flank, and the flat surfaces from the fillets to the angle need not exceed 4 inches in width unless the roofs have a very quick pitch. The width between the edges of the slates should be ample, to enable a man to get his feet into the gutter when climbing up it. Where the lengths overlap each other about 4 inches should be allowed for the joint.

Drip-boxes or Cesspools should not, as a rule, be less than 6 inches deep, and where practicable they should be arranged with an open end to discharge into a hopper or rain-water head. When formed in this way choked outlets in the

gutters are avoided, but many cases occur where such drip-boxes cannot be used.

On all buildings where the box type of drip-box is necessary the latter should be provided with an overflow in case the outlet pipe gets choked. There are two principal ways of arranging the outlet pipes from drip-boxes, as illustrated by A and B, Fig. 21. In either case the outlet pipe requires soldering to the drip-box, otherwise an overflow pipe would be no safeguard to prevent leakage should a stoppage occur at any time in the outlet pipe.

If a drip-box is not very deep, the overflow pipe will require to be inserted in a flattened form so as to enable the

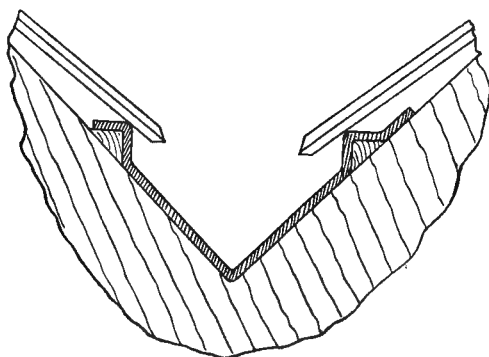


FIG. 20.—Valley gutter, or flank.

whole orifice to be below the gutter end. A simple form of overflow is given at B, Fig. 21, where the end is shown finished flush with the wall.

The question is occasionally raised in connection with drip-boxes, whether those that have their angles bossed are not superior to those that are made with soldered joints? From a practical standpoint, provided that each is well made, one is just as good as the other so far as durability is concerned; generally speaking, however, unless a plumber is a very good lead-worker he makes a better job by soldering deep angles than by bossing them up. The making of drip-boxes in practice is chiefly regulated by their height and shape, the method involving the least labour being the one

usually adopted. For example, if a drip-box like Fig. 22 is required, it is much easier to cut it out of a piece of lead and solder the corners than to boss it up. A cheaper method still of making the drip-box would be to "burn" the angles.

The size of drip-boxes is, of course, regulated by circumstances, but it is desirable that they are not made unduly large or there may be difficulty in getting them into position.

Flashings.—To render roofs water-tight by the side of walls or other structures, lead flashings are usually employed. These flashings take various forms, and different styles of

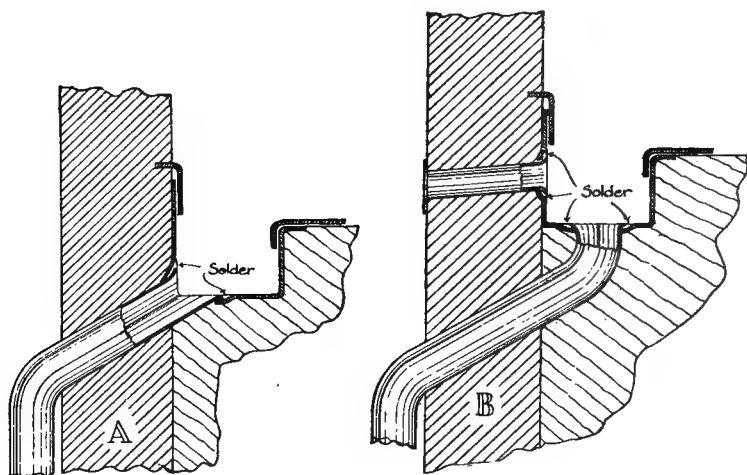


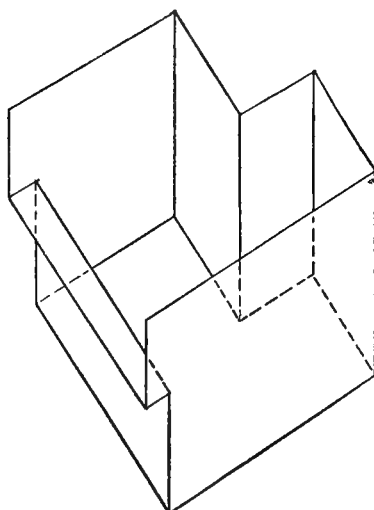
FIG. 21.—Outlets from drip-boxes.

work are carried out for similar purposes in different parts of the country. Plain flashings take the following forms:—

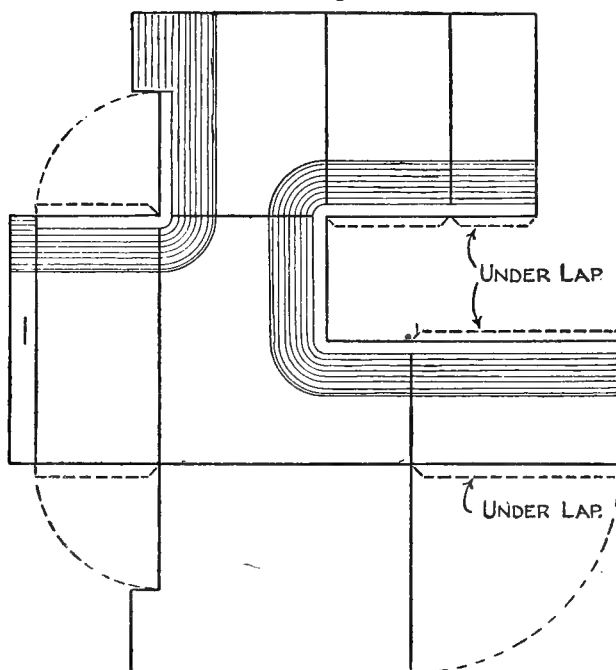
1. Soakers and cap flashings. 2. Cover flashings. 3. Secret gutters. 4. Exposed gutter flashings.

Soakers and cap flashings make undoubtedly the best work, so far as weathering and durability are concerned, but a large part of the work requires to be done on the roof after it has been slated or tiled.

Cover flashings are not suitable for exposed situations, nor for gable walls and similar structures which make greater angles than 90° with the courses of the slates when viewed from below. These flashings, however, are satisfactory for



View of drip-box.



Development of lead for lining drip-box shown above.

FIG. 22.

general work, provided the situations in which they are fixed are sheltered from high winds. Cover flashings are easily fixed, but the greater part of the work requires to be done when the slates are in position.

Secret gutters possess the advantage of allowing the lead-work to be done before the roofs are slated, but they are liable to give trouble by getting choked with moss, leaves, and other débris.

Exposed gutter flashings are similar to the last, but they are wider, and are not liable to chokage as Secret gutters.

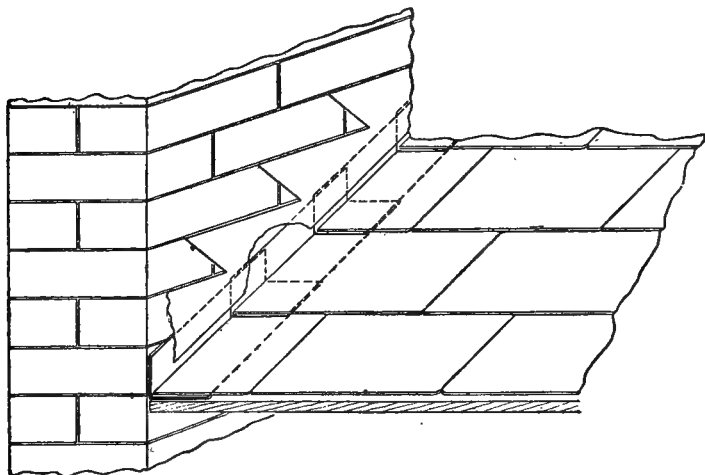


FIG. 23.—Soakers along with continuous step flashing.

The form of roof construction, it will be found, regulates to a great extent the use of any particular class of flashing. In England, for example, it is the general custom (excepting the better class structures) to simply nail the slates to battens or laths, which are in turn nailed across the rafters of a roof. This kind of roof construction, unless specially prepared does not lend itself to either form of gutter flashing, but is better suited for cover flashings and soakers, which are largely used throughout England.

In Scotland roofs are generally first boarded, and the slates are nailed to the boards. Such roofs are therefore well adapted for gutter flashings, and this is probably the chief

reason why the exposed form of gutter flashing is so largely used in North Britain.

In roof work it is a decided advantage to be able to fix nearly the whole of the lead before a slate or tile is in position.

A small portion of a gable wall and roof, Fig. 23, shows how soakers and step flashings are commonly arranged. A soaker is provided for each row of slates, and the lap allowed is the same as that for the slates. As a rule soakers do

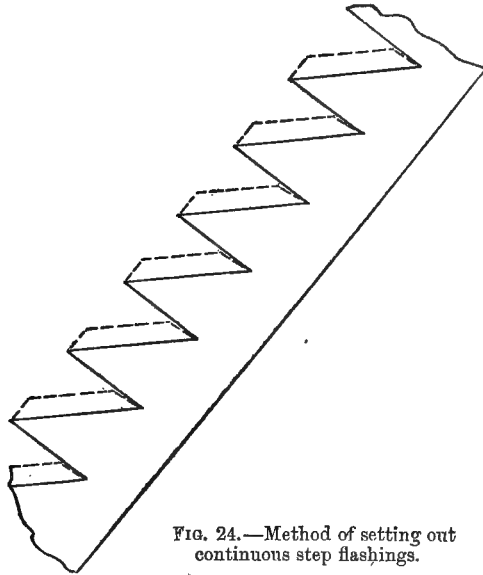


FIG. 24.—Method of setting out continuous step flashings.

not require to exceed 7 inches in width, irrespective of the size of slate; that allows an upstand of 3 inches and 4 inches under the slates. The length of soakers can be found by adding the lap to the full length of slate, then dividing by 2, and by further adding to the result $\frac{1}{2}$ an inch. Thus if slates are used which are 20 inches long, and are laid with a $3\frac{1}{2}$ inch lap, the length of soaker required = $\left(\frac{20 + 3\frac{1}{2}}{2}\right) + \frac{1}{2}$
 $= 11\frac{3}{4} + \frac{1}{2} = 12\frac{1}{4}$ inches.

Step Flashings may be made in single steps or they may

take the continuous form, the latter being represented in Fig. 23. When setting out continuous step flashings it is essential that the lead from which they are cut be wide enough to allow the free edges of the steps to slope well backwards. If the lead is narrow, the free edges of the steps may be nearly vertical, and rain may be driven in behind the lead and leakage may result. The lead to form the steps and to overlap the soakers, as in Fig. 23, should not be less than 6 inches in width. To mark where the

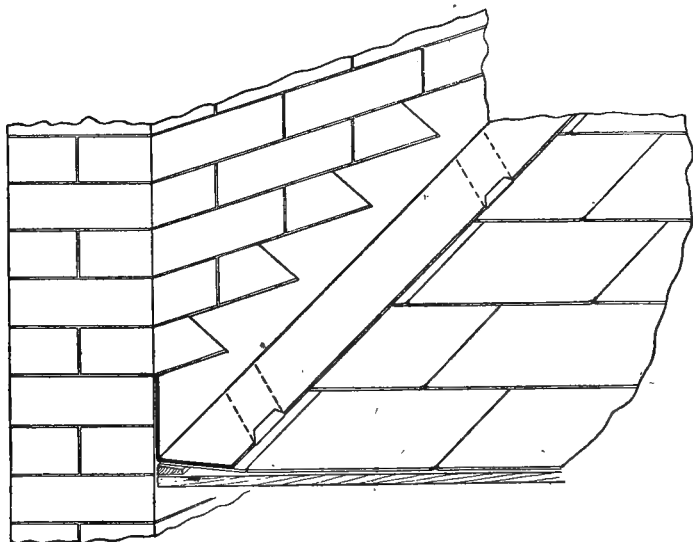


Fig. 25.—Cover flashing.

turnings for brick joints come, the strip of lead should be fixed temporarily in position, when a short straight edge can be laid along the joints and lines drawn from the latter across the lead. After the positions for the turnings have been obtained, an inch or thereabout is allowed on each step for entering the brick joint, and the surplus lead cut out.

Fig. 24 shows how a length of step flashing is prepared, and how it appears prior to turning the allowance at the top of the steps. For exposed situations, the strength of lead for step flashings should not be less than 5 lb. per square foot.

The thickness of the lead for soakers should be regulated by the character of the slating, so as not to unduly tilt the slates. Generally speaking the strength should not exceed 5 lb. per square foot.

Cover Flashings.—In Fig. 25 a piece of *cover flashing* is given, and, as its name implies, the lead is simply secured on the top of the slates, the whole width of the flashing being usually in one piece. The lead which covers the slates is

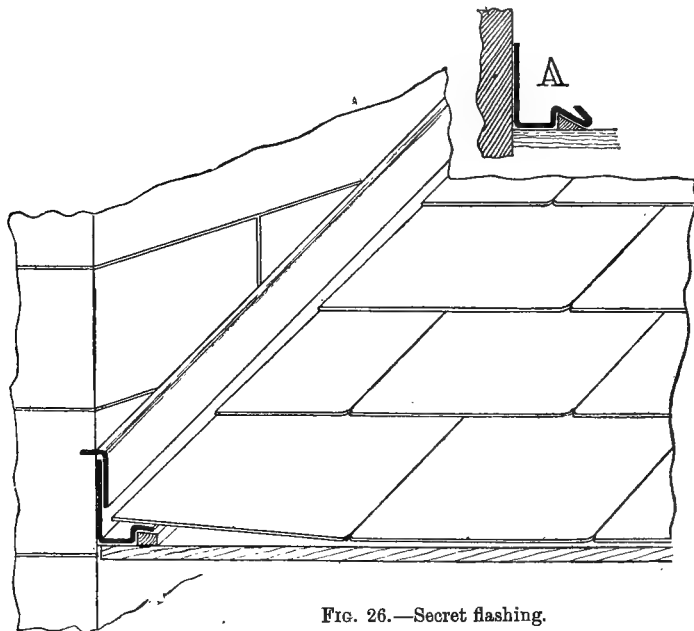


FIG. 26.—Secret flashing.

usually about 5 inches in width, whilst the upstand in which the steps are formed should not be less than 6 inches. Cover flashings should be fixed in comparatively short lengths. To prevent water following between the flashing and the slates, and leaking into the roof, the slates are tilted from the wall by means of a wood fillet, as in Fig. 25. The lead on the slates is held in position by copper or lead ties, which are obliquely fixed, and clipped round the free edge in the manner shown. The ties should not be

less than 2 inches wide, and fixed from 24 to 30 inches apart. Lead ties are not so satisfactory as copper ones, and where the former are used they should be cut from lead weighing not less than 6 lb. per square foot.

Secret Gutters.—The secret gutter flashing, Fig. 26, has a separate cap flashing, the upper edge of the latter being fixed in a groove which is cut in the stonework. Secret gutters are made of slightly varying widths, but, as the term implies, no lead on the roof is intended to be in view. Their general formation is shown in Fig. 26, and the width of lead on the roof surface may vary from $1\frac{1}{2}$ to about $2\frac{1}{2}$ inches. The slates

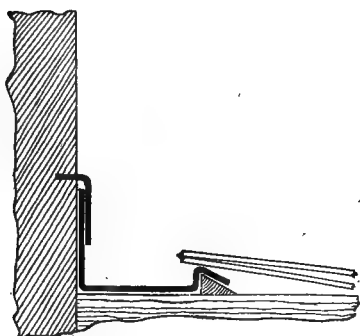


FIG. 27.—Gutter flashing.

cover the channel to within half an inch of the upstand lead. By means of a fillet the outer edges of the slates are raised a little, and this prevents the water following round them, and leaking into the roof.

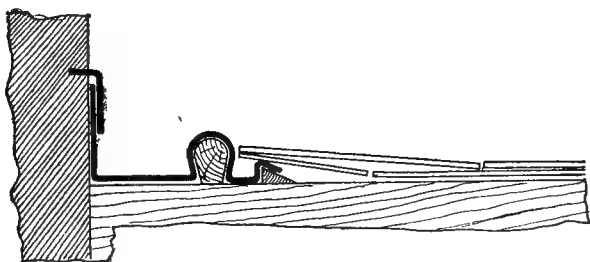


FIG. 28.—Gutter flashing with roll.

Another means to prevent leakage when secret gutters are used is to double the edge of the lead back on the fillet, as at A, Fig. 26. The latter mode of treatment, however, seldom serves any useful purpose, as the slater usually flattens down the free edge on the fillet in order that the slates may have a firm bearing. Secret gutters, as

previously stated, are readily choked, and for this reason there are many situations in which they should not be used.

Exposed Gutter Flashing.—This is illustrated by Fig. 27, and it will be observed that it resembles to a great extent the secret gutter. In Fig. 27, however, the space between the fillet and the wall is usually about 6 inches, and in this case it is not liable to stoppage like a secret gutter as it can be flushed out with a heavy shower of rain. When a moderate volume of water is delivered from a higher to a lower roof, or

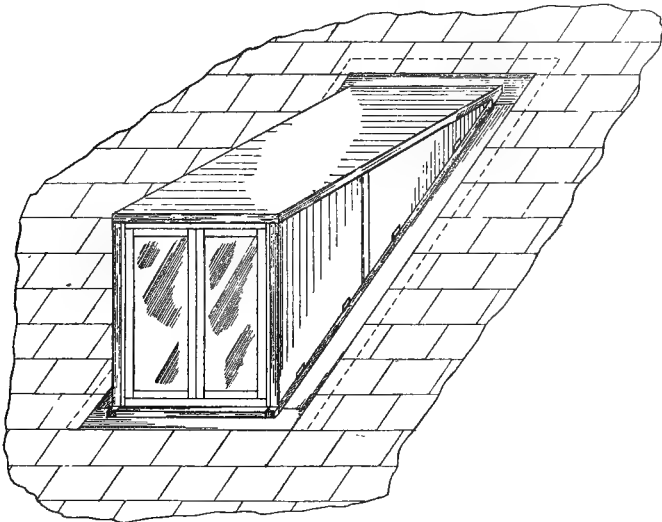


FIG. 29.—Arrangement of leadwork in connection with a plain dormer.

where a large volume of water is likely to flow down an exposed gutter, the latter is usually modified to take the form given in Fig. 28, where the roll prevents the water running over the fillet and getting into the roof.

Dormers.—A method of rendering a dormer in a slated roof water-tight is illustrated in Fig. 29. The apron which lies on the slates at the front of the dormer is first fixed in position, and it should be continued over the framework, with the upper part of the structure erected upon it. Unless the apron flashing is treated in this manner there is difficulty in making a dormer weather properly along the front. Although

the exposed gutter flashing is shown at the sides of the dormer, either soakers or cover flashings may be used instead.

The cheeks or sides are each covered with two pieces of lead, which are joined by vertical "clinked" or "welted" seams. Of course the number of pieces to cover one side would be

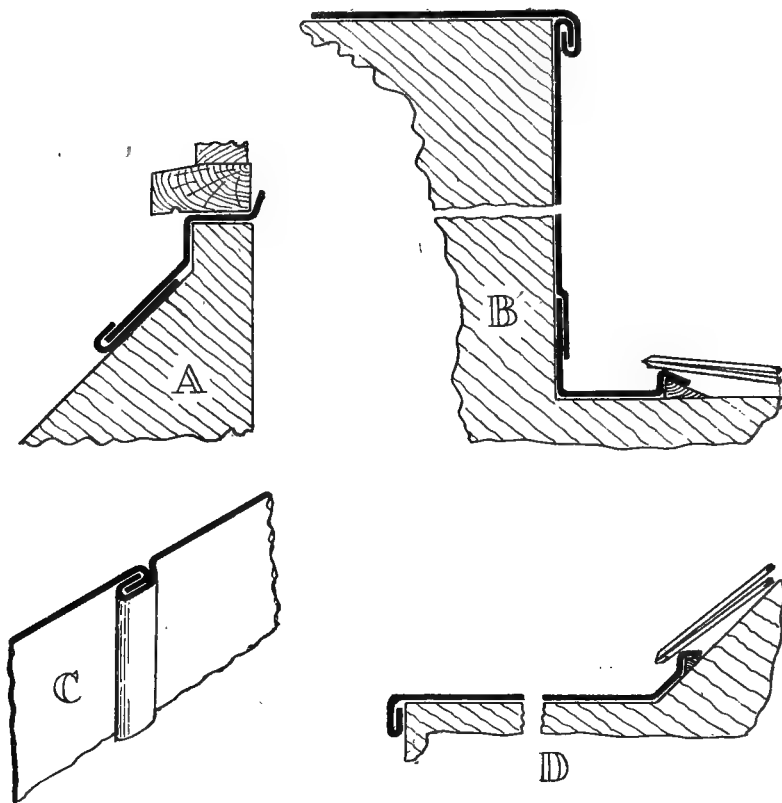


FIG. 30.—Details of leadwork for dormers.

regulated by the size of the dormer. Where the top is comparatively small, as in Fig. 29, only one piece of lead is necessary to cover it, but when large two or more pieces may be essential. The top edges at the front and sides of the dormer are shown with a simple finish, but this part may be made ornamental by introducing mouldings. In

either case the leadwork requires to be well secured along the top edges to prevent its being blown up by high winds.

Enlarged details, Fig. 30, show more clearly how the leadwork in connection with dormers is secured. The apron, or barge flashing, A, it will be noted, after passing over the top of the framework is turned upwards inside. In lantern lights the apron flashings are treated in the same manner, but instead of dressing the lead close to the framework a small cavity is sometimes left between the lead and woodwork, in order to receive and to discharge any water of condensation. B shows how the cheeks and top may be

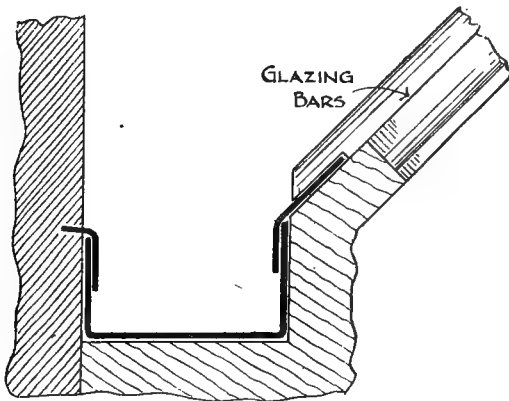


FIG. 31.—Box-gutter between wall and glass roof.

treated, the lead being supported along the bottom edge with suitable ties. At C a vertical clink or welt is given for joining the pieces of lead which cover the cheeks. D shows how the lead is arranged at the top of the dormer; the reason for doubling the free edge of the lead under along the front edge is for strengthening purposes. The lead should also be supported and secured by ties being inserted in the "clinked" or welted seams.

The strength of lead for covering dormers or similar structures should be approximately as follows: Tops 6 or 7 lb. per square foot. Sides and aprons, 5 or 6-lb. lead. Exposed gutter flashings, 5 or 6-lb. lead. Apron flashings should overlap the slates by about 5 inches,

Glass Roofs and Skylights.—When a glass roof drains into a box gutter, as in Fig. 31, it will be found easier and quicker to lay the gutters, if separate flashings are used at the ends of the glazing bars. Where gutters and flashings are combined there may be much difficulty in getting them into position. When separate flashings are used the gutters can be laid in the ordinary way, and it is an easy matter to slide the flashings under the ends of the glazing bars, which have been first slotted to receive them.

The side flashings for skylights may be arranged in different ways, depending upon the circumstances of the case. If soakers are used for the sides of a fast light, which stands 4 inches or so clear of the roof, separate cap flashings are generally used for covering the top edges of the soakers, and to turn over on the upper surface of the woodwork. Where a skylight is only raised a little above the roof, separate cap flashings cannot be used, and under these conditions it is customary to

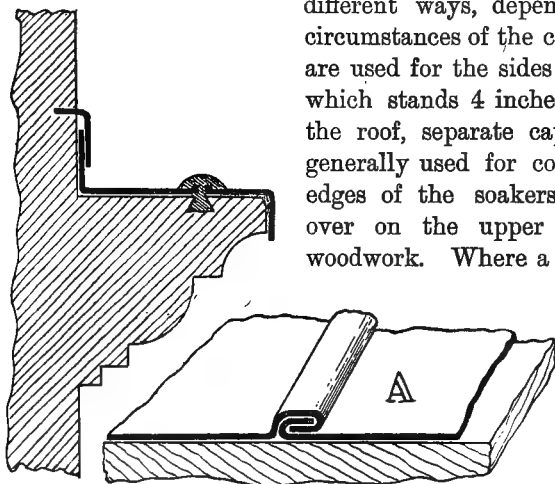


FIG. 32.—Lead covering for stone cornice.

make the soakers with a higher upstand, and to dress the latter over the upper edge of the light. Gutter or cover flashings may be used, of course, in lieu of soakers, but the principle is the same irrespective of the particular kind of flashing which may be adopted.

Cornices.—Both stone and wood cornices are often covered with lead in order to preserve them from disintegration and decay. For covering cornices similar to Fig. 32 the lead is usually cut in lengths equal to the width of the sheet, and the pieces are joined together with clinked or welted seams.

On stone cornices the lead is easily secured in position by means of lead dowels, which are introduced at intervals varying from 2 to 4 feet according to the width of the cornice. The dowels may be formed by cutting dovetailed holes in the stonework prior to the fixing of the lead; upon the latter being placed in position, small holes are bored into it immediately over those in the stonework, when the lead is shaved around the holes and their edges turned upwards,

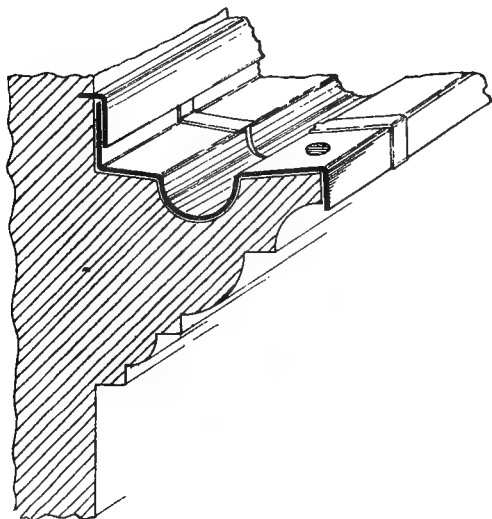


FIG. 33.—Treatment of joint of leadwork in connection with channel cornice.

as in Fig. 32. A brass or iron mould is afterwards placed over the prepared holes, which are run full of molten lead.

Another method of securing lead on stone cornices is to make holes in the latter as above described and to run them full of lead. After the cornice is covered, tinned-headed screws are driven through the sheet lead into the dowels or plugs, and soldered dots wiped over them.

When cornices, such as Fig. 32, are of wood, the best method of securing the leadwork is by means of copper ties, which are fixed in the clincked or welted joints.

It is a good plan to dress the lead square over the edge

of a cornice, and to trim it off so that it may hang free of the stone or woodwork. By doing this an even edge is preserved, and water is prevented from trickling down and disfiguring the moulding of the cornice.

For covering a channel cornice, Fig. 33, the lead is laid in as long lengths as possible, and the joints either soldered or made by burning them. As these cornices are fixed level,

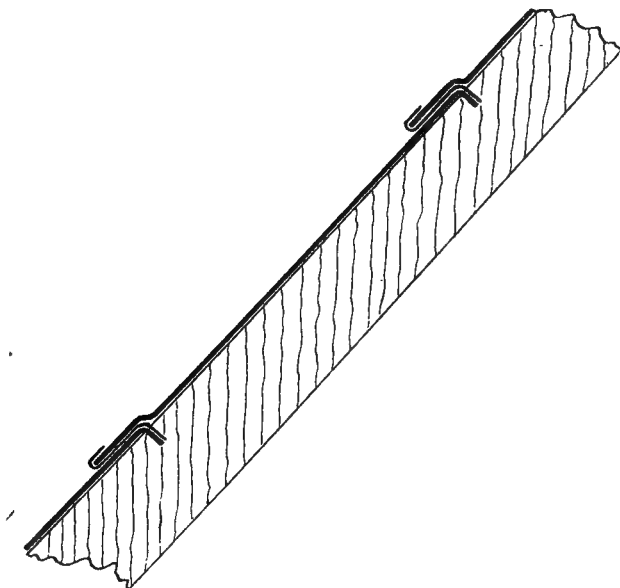


FIG. 34.—Method of covering pitched stone copings with lead.

the only fall available is that obtained by cutting the channel deeper as the outlet is approached than at other parts. The joints in the channel should be made flush on account of the small amount of fall obtainable. It is not necessary to solder or to burn the joint right across on a channel cornice, but a clincked or welted seam can be used excepting for the channel itself.

Pitched Stone Copings.—Sometimes it is essential to cover pitched copings with lead, but the general method of securing the leadwork with dowels or dots is not satisfactory in this

case. Dowels or dots form rigid fixing, and although they answer for cornices more freedom for movement is necessary when supporting heavy pieces of lead on comparatively quick pitched surfaces. A good plan of securing leadwork on pitched copings is indicated in Fig. 34. The length of each piece can be regulated to a great extent by the pitch of the coping, but in any case the pieces should not be very long. It will be observed, upon reference to Fig. 34, that the top end of each piece of lead is turned into a groove in the stonework, and in the same groove copper ties are introduced for supporting the next higher piece. Thus each piece of lead is well

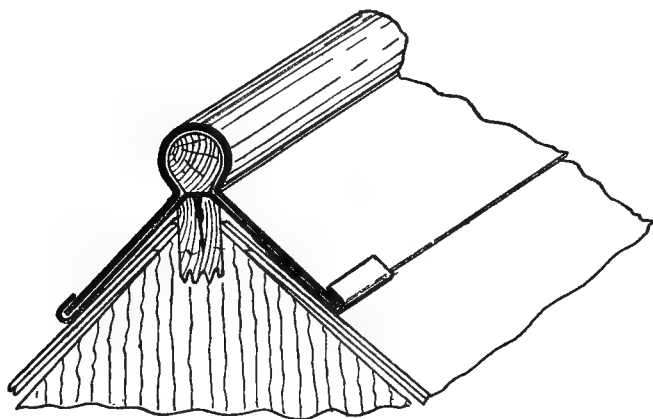


FIG. 35.—Method of securing lead on ridges with copper ties.

secured along the top and bottom edges, and yet sufficiently free to allow a little longitudinal and lateral movement.

Hips and Ridges.—Rolls for ridges and hips require to be raised above the slates that the lead may be able to grip them without pressing upon the edges of the slates. An old but very good method of arranging these rolls is that of fixing them on spikes, which are first driven into the ridge and hip timbers.

Another method is shown in Fig. 35, where the rafters are arranged to come below the top of the ridge piece, and where the edges are chamfered that the top of the ridge piece may be no wider than the bottom of the roll.

For general work, ridge and hip rolls are similar in size to those for flats, but larger ones are used for special work. The lead wings which overlap the slates should not be less than 5 inches in width, and where ornamental wings are desired greater widths will be necessary.

Fixings for Hips and Ridges.—The lead on ridge and hip rolls requires to be specially well secured, or it is liable to be dislodged by high winds or to “creep” down the hips by its own weight. *Copper or lead ties* are frequently used, as in Fig. 35, so as to grip the lead on each wing and to keep it

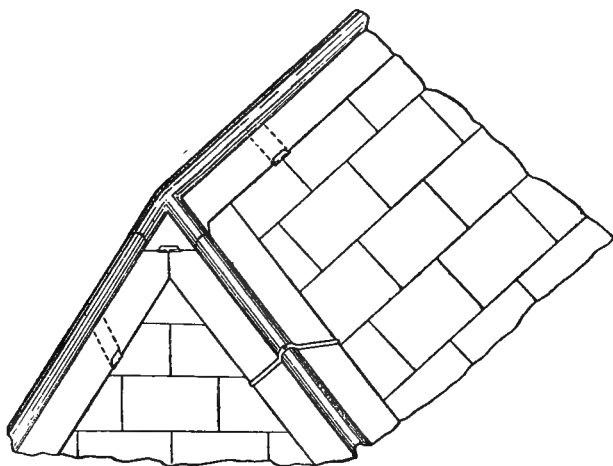


FIG. 36.—Method of securing lead on hips or peends.

tight on the roll. The ties are fixed prior to the wood roll, and spaced about 2 feet apart.

On the right hip in Fig. 36 the lead is fastened by *copper or galvanized wrought iron bands*; they take the form of the roll, and are turned under the edge on each side of the wings. The bands are screwed or nailed down on the rolls.

Secret fixings, which consist of small pieces of lead about 4 inches long, are sometimes soldered on the under side of the lead at the top of the rolls; these fixings are dressed round the rolls and nailed down, whilst the lead for covering the rolls remains boxed up in the usual way. For good work, secret fastenings should be sunk flush with the top of the

rolls. They are very serviceable for securing the lead on quick pitched hips where a neat form of fixing is required.

Lead-headed nails, along with the use of copper ties, make simple and cheap forms of fixings, and are effective for holding the lead in its place.

Bossing the lead round the ends of rolls is a practice occasionally adopted when covering large rolls on very quick pitched roofs. The wood rolls should be in about 5 or 6 feet lengths, and after the bottom one is fixed it is covered with lead; the lead itself is left longer than the wood roll, the surplus portion being bossed over the upper end to afford a means of support. After the first length is finished another is placed in position, and the same process is repeated. This procedure is followed until the hip is complete.

The precise method of securing lead on ridges and hips is chiefly regulated by their situation and the shape of the rolls. It is clearly obvious that the same amount of fastening will not be necessary in sheltered places as in situations which are exposed to high winds. Rolls when not of a good shape may require additional fixings on that account.

Ridge rolls, like Fig. 35, when covered with 5 to 7-lb. lead admit of the latter being well secured with ties, but these fixings are liable to failure unless the rolls are suitably shaped and the ties freely used.

Ordinary ties, as in Fig. 35, are insufficient fixings for hip rolls, and additional fastenings should be used.

Galvanised iron or copper bands when fixed on rolls do not present a neat appearance, but they have the merit of being easily fixed and are effective so far as securing the lead is concerned.

Secret fixings are very suitable where strong, neat work is required, but their use makes the lead more costly to lay on account of the extra labour they involve.

Where two lengths of lead are joined on ridges they should overlap each other by about 4 inches; on ridges the overlap should not be less than 3 inches.

Ornamental Ridging.—On many public and other buildings ridges are frequently of an ornamental character, and some particular design is either cut or formed in the wings of the

leadwork. In these cases the rolls are much larger than those generally employed, so as to give them a prominent appearance when viewed from a distance. As the lead for ornamental ridgings requires to be wide it is often necessary to fix it in two or more widths, and afterwards to clink or welt them together.

When various designs require to be bossed on the wings of the leadwork, the wings should be separately fixed so as to permit of the work being more readily carried out. Suitable blocks can often be screwed to a bench and the lead worked down over them to produce the effect desired.

Torus Rolls.—In Fig. 37, three methods are shown of arranging the flashings in connection with a mansard roof or similar structure. When rolls are used at the break, the lead to cover them requires to be well secured, or it will work loose upon the rolls and probably be displaced by gales. There are simpler methods than those shown for fixing lead on torus rolls, but they are not so effective.

At the eave of the higher portion of the roof a fillet is provided, as it is imperative that the slates be firmly laid if they are to be prevented from dislodgment in boisterous weather. At A, Fig. 37, the apron flashing is first fixed in position; then the lead which covers the roll is secured along the top of the first flashing; the wood roll is afterwards fixed, and the last piece of lead is then turned upwards and over the roll, the lead being finally secured by nailing it along its top edge. This method of covering a torus roll will not be suitable for every case, and unless the lead is fixed in comparatively short lengths there will be trouble in getting it tight on the roll.

A different but good method of covering torus rolls is indicated by B, Fig. 37, but it takes a little more lead than that given at A. The apron flashing, as before, is placed first in position, and on that a narrower strip is fixed for the whole length of the roll. The wood roll is then fixed, and this is covered by another piece of lead from the higher roof. The strip of lead immediately at the back of the roll is then turned forward under it, and with this is joined the lead from the upper roof by means

of a clinked or welted seam as shown. To obviate a large bulge being formed along the bottom of the roll, the strip of

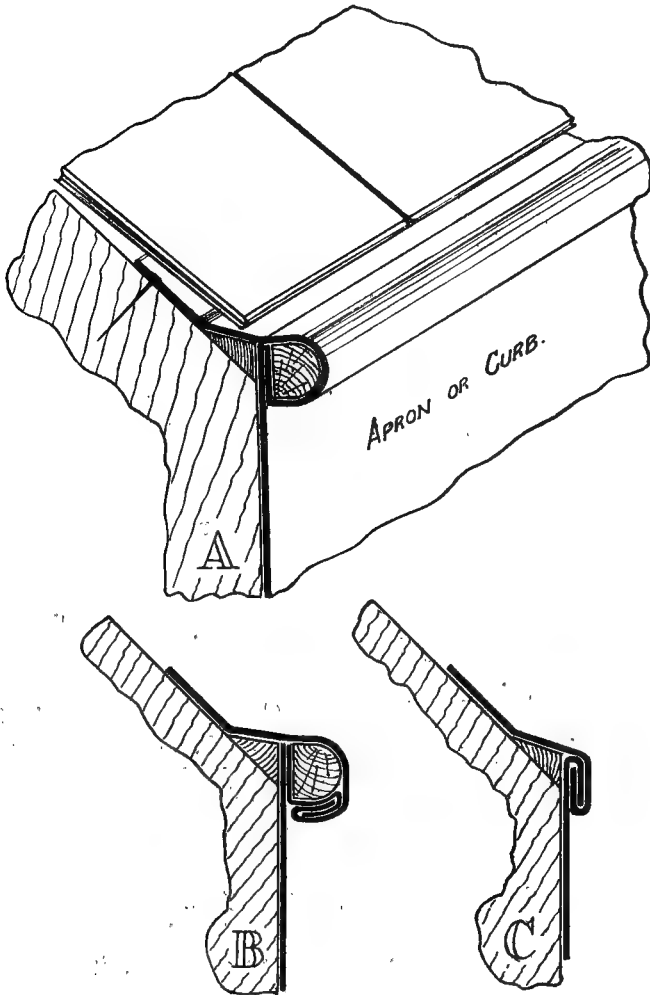


FIG. 37.—Treatment of "torus rolls" or "bottles" when in exposed situations.

lead immediately behind the roll is usually thinner than that covering the other parts.

When rolls are omitted, a simple but effective method of securing the lead flashings is that illustrated at C, Fig. 37.

Turret Roofs.—The leadwork in connection with turret roofs is often of an intricate nature, and especially when the turrets take a very ornamental form. It is specially advisable in this case to keep the pieces of lead as small as practicable, as they can be the more readily fixed and secured.

Fig. 38 indicates a ventilating turret which is located at the top of a span roof. At the base it is square on plan, whilst the louvred portion and roof take a hexagonal form. For covering the lower and plainer part of the structure, the lead may be arranged in vertical bays as shown, the pieces being joined with clinked or welted seams. Copper ties would be necessary both along the bottom edge of each bay and in the seams for securing the leadwork. Before the bays are formed the apron A and flashings G would of course be placed in position. If a bolder form of joint is desired for the vertical bays, hollow rolls can be used in lieu of flat seams. Solid rolls are not so suitable as the hollow ones in this case. On the other hand, however, if the rolls were diagonally placed, solid ones would be preferable, and the work could be executed much more quickly than if hollow rolls were adopted. The lead flashings between the bays B and the cornice C may be arranged in a number of separate pieces as shown.

When dealing with the cornice C each section should be covered separately, and the lead well set in so as to take the correct shape of the moulding. For joining two pieces of lead on the cornice, clinked or welted seams may be used, the latter being formed on one side a little removed from a mitre.

For covering a turret roof, such as that in Fig. 38, either solid or hollow rolls may be used, although the latter are preferable for the shape given. In the Fig. it will be observed that the rolls are nearly vertical for a portion of their length. If solid rolls were used for such a case it would be desirable to support the vertical portion of each bay with secret ties in addition to the usual fixings. The lead covering the cornice C should be continued up the roof for a distance

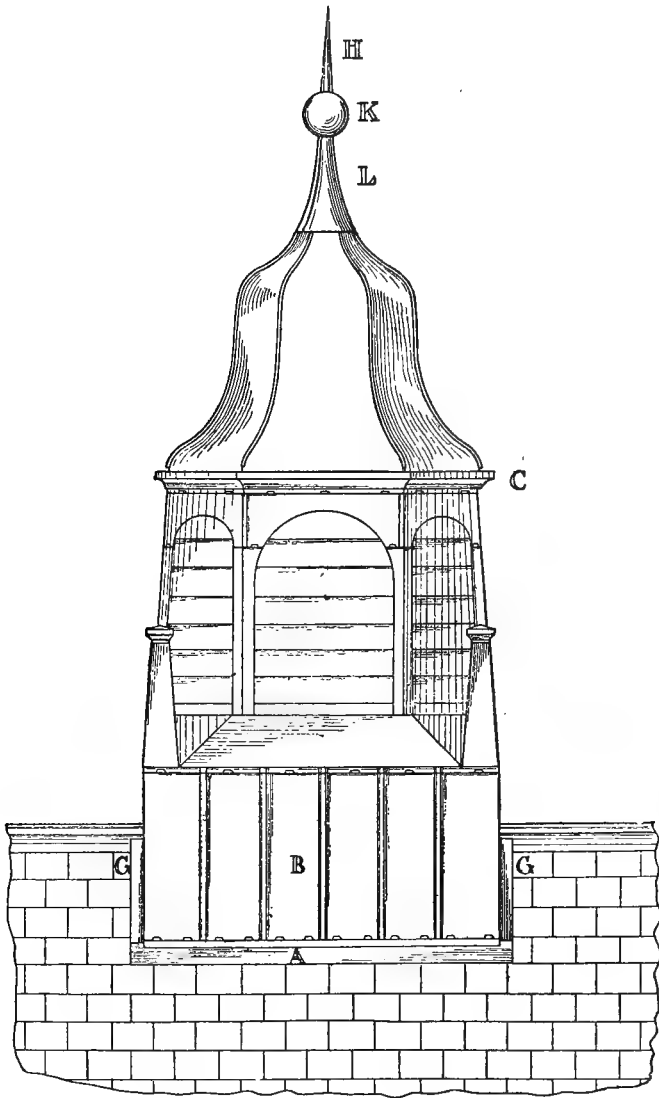


FIG. 38.—Method of covering turret with sheet lead.

of say 5 inches, so that the rolls and bottom edge of the roof bays may be trimmed clear of the cornice. The upper

end of the rolls would be capped with the lead which covers the base of the finial.

On large turret roofs intermediate rolls would be required, and the bays may require to be covered with two or more pieces of lead.

Shape of Bays.—In practice, the shape of the lead for covering a bay on a turret roof is not a very difficult matter to obtain. A simple method of determining the true shape is as follows: First strike a line from top to bottom down the centre of the bay. At right angles to the centre line set off a number of other lines down the whole length of the bay, at convenient distances apart. The closer the parallel lines are drawn the better, but 6 to 12 inches apart (depending on the size and shape of the turret) will, as a rule, be suitable for general work. All the lines should now be measured and their lengths noted. It will be found convenient, if a rough sketch of the bay is made in a pocket-book or on a piece of wood, to show all the lines which have been marked upon the roof, together with their lengths. The length of the centre line over the curved or irregular surface may be measured with a tape. All the lines are reproduced on a suitable piece of lead, and their exact lengths marked off. Through the measured points on the parallel lines free-hand curves may be drawn, when the true shape of the bay will be obtained. The allowance of lead for the rolls or other laps is afterwards added.

When the shape of one bay has been obtained, it is used as a template for the remaining bays; corrections, however, may be necessary, as the dimensions of similar parts of different bays often vary slightly.

Frequently the shape of half a bay is obtained in the manner above described, and cut out in either zinc or thin sheet lead; this is simply used as a template for the other bays, and admits of any little alteration being readily made. As before, the allowance for laps and rolls is afterwards added.

When the shape of a bay for a turret or similar roof requires to be produced from drawings, the exact dimensions may not admit of direct measurement, see Fig. 39. To

determine the shape of a bay in this case, first draw to scale a part section and plan of the structure, as A and B, Fig. 39. Divide the curved line of section A into any given number of parts, making them equal as far as possible for the sake of simplicity; so far as exactness is concerned the more parts into which the line is divided the better. Next set off a line in plan B at right angles to the centre of *xy*, so as to divide the plan of one bay into two equal parts. From the numbers on the curved line of section A, drop perpendiculars to pass through the plan as in B, and number as shown. Next draw a line *mn* as

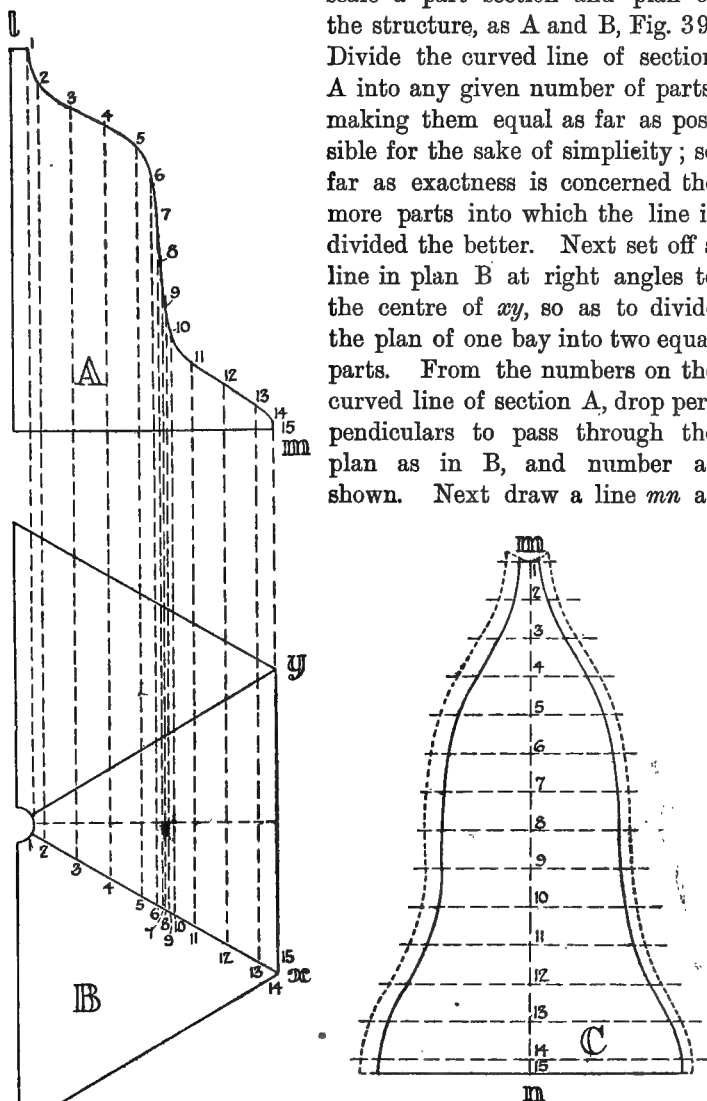


FIG. 39.—Method of obtaining true shape of leadwork for a bay from drawings.

in C, Fig. 39, and at right angles to it draw a number of horizontal lines exactly the same distance apart as the divisions on the curved line in section A, and number in like order. The widths for the different parts of the bay are obtained from the plan B by taking the distances between

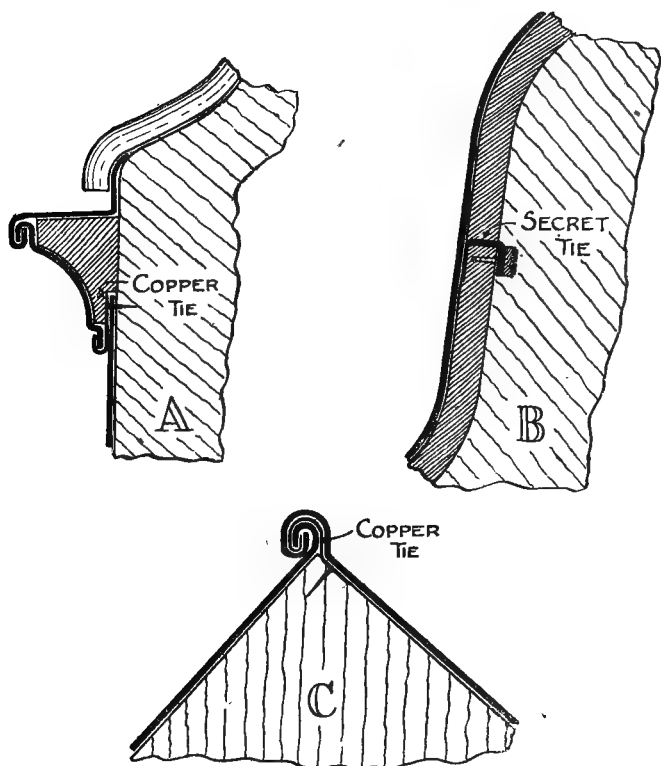


FIG. 40.—Details of lead for turret roofs.

the hips and reproducing them on the lines with like numbers in C. Join the points obtained by freehand and the correct shape or development will be obtained. The allowance for rolls is then added and is represented by the dotted lines in C.

The finial at the apex of Fig. 38 may be covered with three pieces of lead: the first piece, L, caps the rolls and

covers the base of the finial; the second piece covers the ball K, and the third the top part H.

Details of Turret Roofs.—Fig. 40 gives a few details in connection with these roofs. At A is illustrated how a plain cornice may be covered; B indicates how secret ties

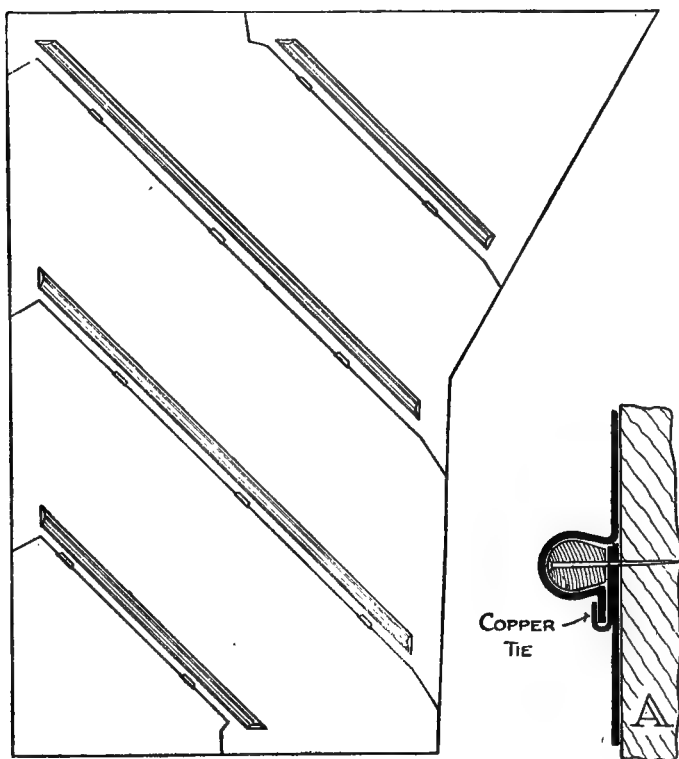


FIG. 41.—Method of securing leadwork on vertical or quick pitched surfaces with solid rolls.

may be utilised for securing rather wide pieces of lead, and for keeping the leadwork close to the boarding where it tends to draw or fall away. The ties are soldered on the under side of the lead, and they can be either screwed to the face of the woodwork or passed through a slot and secured inside the structure, as shown in B, Fig. 40; the

latter method makes substantial fixings when it is practicable to adopt it.

A cross section of a hollow roll and copper tie is given at C, Fig. 40.

Domes.—The leadwork for covering domes is arranged

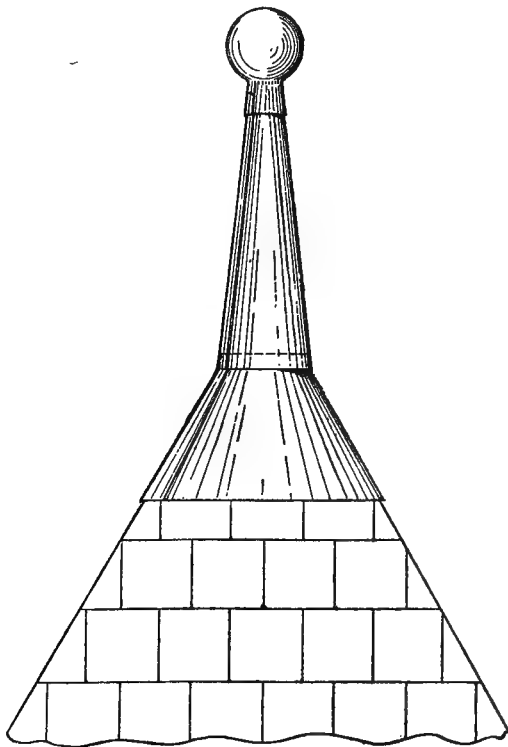


FIG. 42.—Finial covered with three pieces of lead.

and set out in a similar manner to that given for turret roofs: Solid rolls are well suited for hemispherical domes, as the bays gradually increase in width for their whole length; if the work is properly carried out it is scarcely possible for the bays to slip, on account of the grip the under and overcloaks have upon the rolls. Wood cores, however, should be well undercut to give the lead a firm hold, and secret

fastenings may also be necessary in certain cases in the widest parts of the bays.

Covering Vertical Surfaces.—Fig. 41 shows how solid roll work may be carried out for vertical and quick pitched surfaces. Instead of the undercloaks being turned over the rolls they may be left flat, and the wood rolls planted over them and screwed down as shown by the enlarged detail A. When

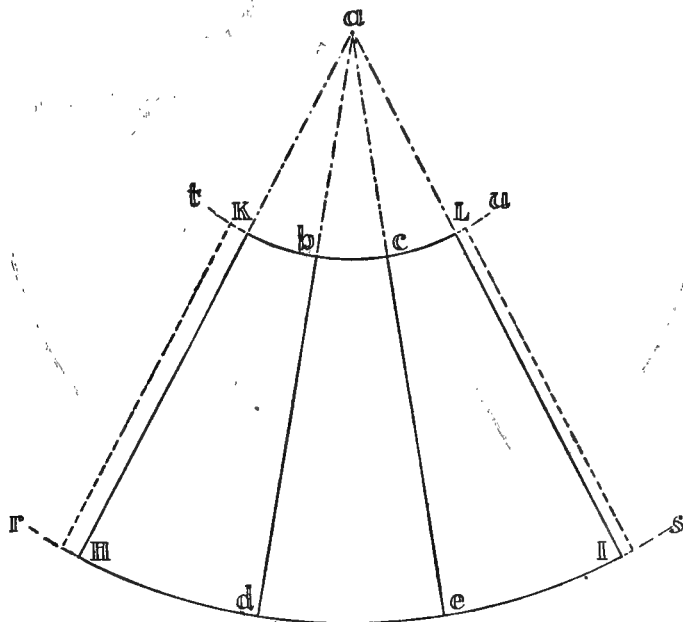


FIG. 43.—Method of obtaining shape of lead for covering centre part of Fig. 42.

the work is executed in this way the undercloak of each bay is securely held in position, whilst each roll also forms a substantial support for the bay immediately above. The overcloaks require to be made secure by copper ties, and the rolls may often be cut a little short to simplify the work, as in Fig. 41. The ordinary method of treating the undercloaks is neither necessary nor suitable for vertical or very quick pitched surfaces. It is advisable to keep the bays as narrow as possible, especially for vertical surfaces.

Finials.—These take a large variety of forms, and the methods of covering them will depend upon their size and shape. A simple form of finial which is situated at the apex of a conical shaped roof is given in Fig. 42. The flashing which covers the upper ends of the slates, and also that which covers the trunk of the finial, represent frustums of cones.

A simple method of obtaining the development of a frustum of a cone sufficiently accurate for practical work is shown in Fig. 43. First draw an exact section of the frustum under consideration, say *bcedb*, and prolong lines

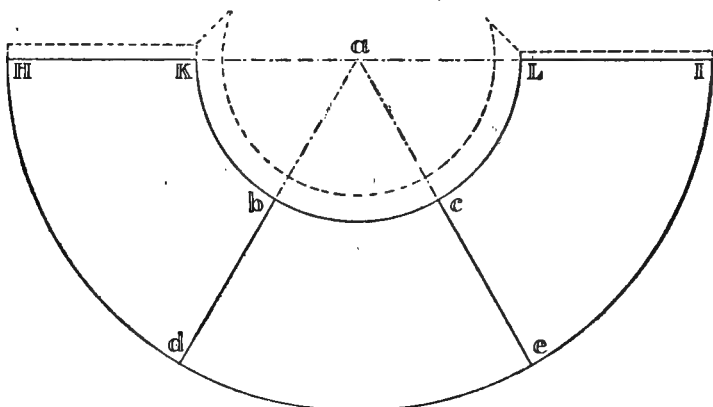


FIG. 44.—Shape of lead for covering base of Fig. 42.

db and *ec* until they meet as *a*. With *a* as centre and radius *ad* describe the arc *rs*; with the same centre and radius *ab* describe the upper arc *tu*. On *rs* point off the distances *dH* and *eI*, making each equal to *de*. From *H* and *I* draw lines to *a*, cutting the arc *tu* at *K* and *L*, when *KLHKL* will be the development required. The correct girt of the base may be tested by means of a tape or by a piece of string. Allowance for laps or joints will require to be added, as shown by dotted lines.

In Fig. 42 the lead which covers the lower frustum is carried up a few inches on the trunk which forms the higher frustum; as these have different pitches, an allowance must be made, as shown by the curved dotted line in Fig. 44, otherwise the lead forming the lower frustum will not girt

the trunk of Fig. 42 where the overlap occurs. After the correct shape has been obtained, it can be bent round the structure, excepting the allowance for the overlap, which will require to be bossed into position, and any surplus lead cut off. After the first two pieces of lead for Fig. 42 are in position, the top may be covered by bossing a circular piece of lead in the form of a cup, and afterwards finishing it in its place.

Finials which are comparatively small in size are occasionally covered with one piece of lead, this being bossed to something like the shape required and afterwards completed in its place.

In other cases, where a simple form of finial is to be dealt with, the approximate development is cut, when the lead is partly bent and partly worked into its place. Care, however, in these cases requires to be taken when setting out the lead, so as to have it sufficiently large at all parts.

Where finials are built up in sections, and are held together by iron rods passing through them, the upper portions can be removed, whilst those immediately beneath receive attention.

Finial Fig. 45 is shown with a circular base, and is covered with five pieces of lead. For the base A the lead may be roughly bossed to the required shape and finished in position. Should the base A, however, be square on plan, it would be easier to cover it with four pieces of lead with joints formed at the angles. The part B can be dealt with by first bossing the piece of lead dome-shaped, and afterwards finishing it off as shown. The small column C may either be covered with a piece of lead pipe or sheet lead suitably formed, whilst the ball D may be covered as before described, and trimmed off about 3 inches down on column C.

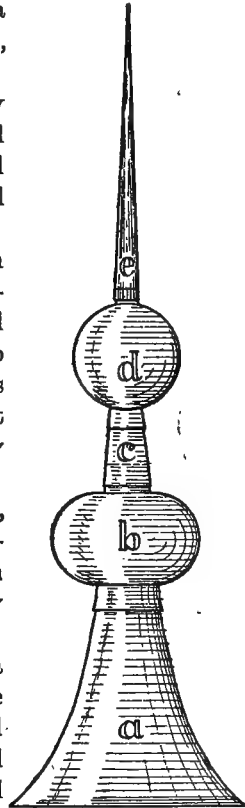


FIG. 45.—Finial.

For covering the conical part *c* a piece of pipe may be dressed to the shape required, or it may be covered with sheet lead, the edges of which are joined by burning or by other suitable means.

TABLE I.

STRENGTHS OF LEAD FOR ROOF WORK

Gutters	5 to 7 lb. per sq. foot.
Flats	6 to 8, " " "
General flashings	4 to 7 " " "
Under flashings or soakers	3 to 5 " " "
Hip soakers	2 to 3 " " "

CHAPTER III

PIPE FIXING AND PIPE BENDING

THE methods of supporting and of fixing pipes are chiefly determined by the metal of which they are made, the purposes for which they are to be used, the situation in which they are to be placed, the kind of structure to which they require to be fixed, and their size.

The old method of burying small pipes in the plaster-work of walls is now nearly obsolete on account of the inaccessibility of the pipes and the damage done when repairs require to be effected. Most of the important pipes in modern buildings are fixed either in exposed positions or in accessible situations. Of course special cases do occur where pipes cannot be made readily accessible, but under these circumstances extra precautions should be taken to prevent them failing at these points.

Lead water pipes are frequently fixed directly to wood grounds in the case of plastered walls, and the pipes can be neatly and readily secured in this way. Where cheap fixings are necessary either malleable or tinned iron clips can be used. Lead clips are not suitable for supporting the weight of a pipe, unless they are strongly made and soldered to it. Cast lead lugs, however, when soldered to the back of pipes, make substantial fixings, and many have a neat appearance.

Although lead fixings can be readily procured many plumbers prefer to make their own. This may readily be done, for, after a suitable design has been decided upon, a cheap mould may be formed in either plaster or lead.

When numerous fixings are required it is better and cheaper in the end to procure gun-metal or iron moulds.

Plaster moulds are readily chipped, and their life is comparatively short, but new ones, of course, can be readily made. Such moulds, however, require to be slowly and thoroughly dried before use if sound castings are to be produced. Lead moulds with care are fairly durable, but after a number of castings have been made they get very rough, when much time is absorbed in trimming the castings to make them moderately smooth. Before using lead moulds they should be well smeared with plumbers' black. Clips or lugs on small vertical lead pipes should be fixed about 2 feet apart, and a little closer on horizontal pipes.

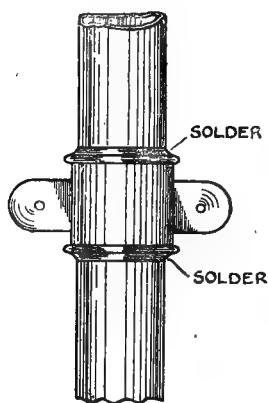


FIG. 46.—Lead socket soldered to pipe.

Wood Grounds are sometimes finished flush with the plaster-work of walls, but they are better when fixed on the face of the plaster; in the first case the plaster is liable to crack and to leave the edges of the boards, either by the latter shrinking or by jarring the boards when fixing the pipes. Lead pipes which are horizontally arranged, and convey hot water, should be supported on wood fillets.

When lead clips are used for securing long lead waste pipes which are alternately heated and cooled, the clips should not be soldered to the pipes, unless the joints will yield.

By the use of iron hooks lead pipes are often distorted or bruised, but this can be avoided to a great extent by placing a strip of sheet lead about $\frac{3}{4}$ inch in width between the pipes and heads of the hooks. Iron hooks as a rule are not satisfactory fixings for lead pipes, but of course they possess the advantage of comparative cheapness.

Large Lead Pipes.—The fixings for lead soil pipes and rain-water pipes may take the form of cast lead sockets, plain or ornamental lugs or tacks, iron brackets, and lead flanges, etc. In Fig. 46 a cast lead socket is shown; it is sufficiently large to slip over the pipe, and it is secured by soldering at both ends to the pipe as shown. Sockets make

good and substantial fixings when fixed at suitable distances apart. Sheet lead tacks, Fig. 47, only support the pipe at the back; they are usually soldered as shown, to enable the pipe to fit close to a wall, although the soldering may be done at the front if desired. When plain tacks are used, they are frequently made sufficiently wide so as to enable the nail heads to be covered by doubling over their free edges and dressing them down, as indicated on the right side of Fig. 47.

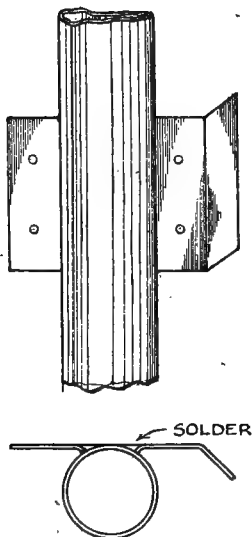


FIG. 47.—Plain lead tacks.

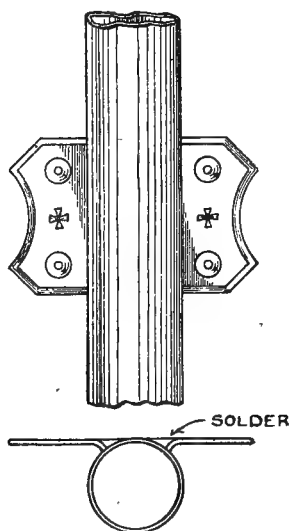


FIG. 48.—Ornamental lugs or tacks.

Ornamental lugs or tacks, Fig. 48, are cast in moulds. Cast tacks make better fixings than those made from sheet lead, as they are thicker and stronger; they are usually soldered to the back of the pipes, so that no solder is exposed to view.

When tacks are in pairs, as in Figs. 47 and 48, they are frequently fixed to 5 feet centres with 10 feet lengths of pipe, and to 4 feet centres with 12 feet lengths, the latter being the more suitable distance apart. Should single tacks be used they should be half these distances apart, and fixed alternately on both sides of the pipes. Not less than two nails

should be used for each tack ; in the case of brick walls the nails would be the same distance apart as the joints, and for stone walls they need not exceed 4 inches apart. The minimum width of lead tacks for large pipes should be about 6 inches.

Ornamental fixings, as in Fig. 49, may be formed from one piece of sheet lead if desired. In this case, after the piece of lead has been cut to the required width, the astragals may

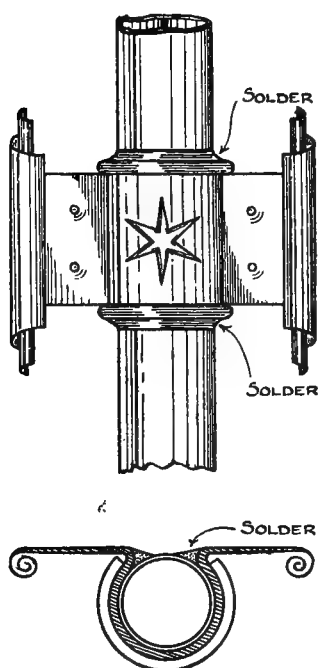


FIG. 49.—Ornamental fixings.

be formed by driving the lead into grooves in an oak block by means of a blunt chase wedge or by other suitable tool. The lugs or ears may then be cut to the required design, when the centre portion may be formed by bending it round a wood mandril or length of iron pipe. Should scroll ears be adopted, as in Fig. 49, these can now be shaped, and the whole afterwards burned or soldered to the pipe down the back and round both astragals. The star or other ornamentation could either be cast, or cut from sheet lead and sweated on with solder. If desired, the star could be carved in the oak block in which the astragals are formed, and made by bossing the lead into it.

Fixings for square and rectangular lead pipes are often of an ornamental character, but as these pipes are chiefly used for discharging rain water from the roofs of buildings, the upper end of each length is prepared so as to serve as both joint and fixing. Socketed joints for square lead pipes are sometimes formed as in Fig. 50, where a spigot piece is inserted and soldered or burned to the pipe. The astragals and tacks are separately attached, and the intermediate fixings are arranged in the same manner excepting that the joint is absent.

Sockets for square and rectangular lead pipes are much more

satisfactory when separately cast, as they can be made to slip over the pipes, and the contractions at the joints, as in Fig. 50, avoided.

Where large lead pipes are fixed in chases or recesses inside buildings, the simplest means of supporting them is shown in Fig. 51. The worst feature with regard to chases is that they are seldom large enough, so that the pipes are not so accessible as they should be. Flange fixings, Fig. 51, can often be adopted where pipes pass through floors.

Iron and Copper pipes, owing to their greater rigidity, can

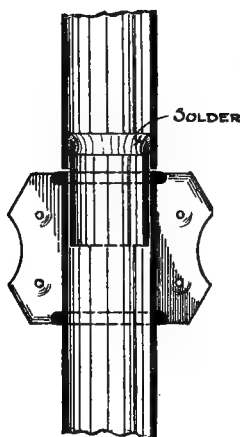


FIG. 50.—Slip joint and ornamental fixing.

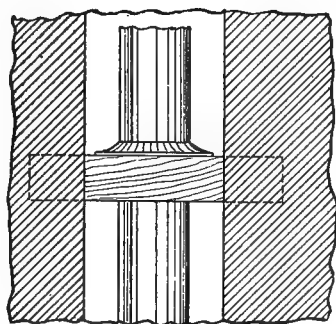


FIG. 51.—Flange support for pipe.

be fixed in a different manner to lead pipes. Small iron pipes when fixed to woodwork may be secured by clips in the ordinary way, but they may be spaced further apart than in the case of lead pipes.

A convenient form of hanger for securing a pipe beneath a ceiling is illustrated in Fig. 52. The loop that directly supports the pipe is made in two parts, and bolted together as shown.

Another hanger suitable for fixing to a steel girder is given in Fig. 53; this has a swivel joint which enables the pipe to be placed in any position relative to the girder.

Hangers like Figs. 52 and 53 are made in malleable iron, and are comparatively cheap.

The silver-plated and lacquered copper pipes that have come into more general use in good buildings for waste and service pipes in connection with sanitary fittings are frequently fixed clear of walls so as to admit of their being readily kept clean. For supporting such pipes two neat forms of brass fixings are given in Fig. 54. That at A is suitable for brick and stone walls, and the one at B for fixing to wood-

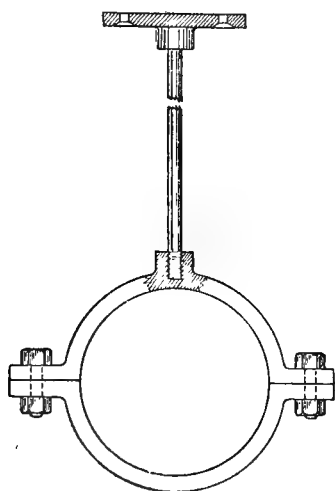


FIG. 52.—Pipe hanger.

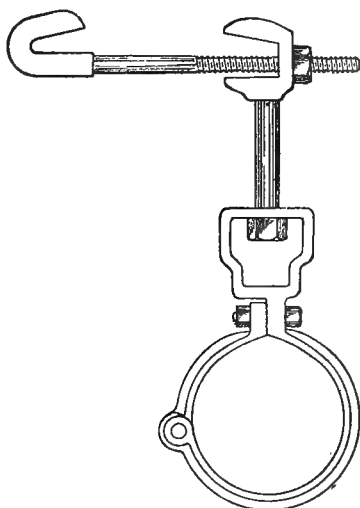


FIG. 53.—Pipe hanger with swivel joint.

work. The part which grips the pipe is made in two parts, and is neatly joined at the front and shoulder as shown. A small dowel keeps the movable part of the clip in position at the front, whilst at the shoulder a set screw is used.

Cast iron brackets make substantial fixings for heavy iron pipes where the latter require to be made secure either on the face of a wall or by being built into it.

Fig. 55 gives a roller bracket for supporting steam or hot-water pipes along a corridor or similar wall.

Another roller fixing, Fig. 56, is suitable for supporting large steam or hot-water pipes when fixed in a

subway or passage clear of the walls. In this case the roller is supported on a light steel girder, which is fixed across the opening. Roller fixings may also be readily designed for supporting pipes beneath girders, and in other situations, when it is found advantageous to do so.

Bending Pipes.—The method of forming bends on lead pipes is regulated to a great extent by their size, by the radius of the bends, and by the thickness of the pipes.

Bends should be made as easy as practicable, for when

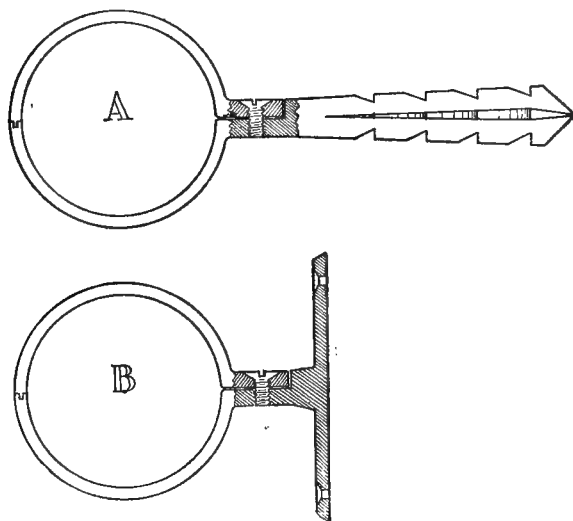


FIG. 54.—Fixings for light copper pipes.

sharp they unnecessarily retard the flow of liquids and gases through them; the metal is also unduly strained during the bending process, and in the case of pipes of large diameter quick bends take longer to make.

Springs are largely used for preserving a uniform bore when bending lead pipes, and they answer admirably for pipes up to $1\frac{1}{2}$ inches diameter, if the bends are gradually made. Bends may also be formed in 2 to $2\frac{1}{2}$ inch diameter lead pipes with the aid of springs, but when the pipes are thin the back of the bends is considerably reduced in substance, and occasionally torn.

Before a spring is inserted in a lead pipe the latter should first be properly straightened, and all kinks or irregularities removed by driving a bobbin or short mandril through it.

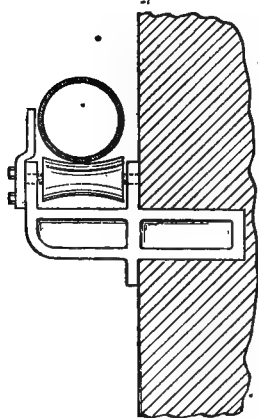


FIG. 55.—Roller bracket.

When a bend is made on thin pipes the sides bulge out a little, and these should be carefully dressed to send the surplus lead towards the back of the bend. The spring can then be withdrawn by twisting to reduce its size and by giving a pull at the same time. The twisting of the spring is not always necessary, and a steady pull will usually suffice to withdraw it provided the pipe has been properly prepared and the bend carefully made.

Many plumbers are too rough with springs, and very quickly strain them by either twisting them the wrong way prior to withdrawal, or by getting them fast in the pipes. In a thin lead pipe a spring does not prevent a small buckle forming at the throat when a bend is carelessly made; should an attempt be made to remove such buckle by dressing up the bend with the spring still inside, the inner surface of the pipe will conform with that of the spring; under such circumstances the spring is fastened in the pipe, and can only be withdrawn by the application of considerable force.

Bends in 2 to 2½-inch diameter light lead pipe are better made in several stages, and at each step the bends should be brought to their normal diameters by either drawing or driving bobbins through them. A small dummy may also be used when bending a 2½-inch diameter pipe.

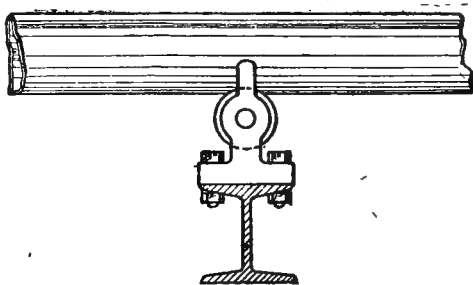


FIG. 56.—Roller fixing.

Slow bends can often be made on light lead pipes of $1\frac{1}{2}$ inches diameter and less by first slightly flattening the sides of the pipes where the bends are to be formed. The effect of bending is to push outwards the flattened parts, when the bends can afterwards be dressed to the required size. Bends may also be easily made in lead pipe up to 2 inches diameter after first loading them with fine sand. Flush and waste pipes can be neatly and quickly bent with the aid of sand, especially when the latter is warm. Prior to bending, the pipes must be well filled, and their ends securely plugged so as to prevent any sand escaping whilst the bends are being made. Bends formed with the aid of sand are preferable to those in which springs are used, as the inner surfaces in the latter case are corrugated with the springs.

Bending Large Pipes.—When bending lead pipes that exceed $2\frac{1}{2}$ inches diameter, dummies are generally used. Large pipes flatten and buckle much more readily than small pipes when bent, and in order to strengthen the back of bends the superfluous lead which gathers at the sides requires to be driven towards that point.

Before bending large pipes a short mandril about 1 foot in length should be driven through them to remove all irregularities, and also to straighten them. An ordinary bobbin is not suitable for this purpose as it only removes the creases or indentations.

To make a bend of 90° on a length of 4-inch lead pipe, not less than five stages of bending should be necessary, and at each stage the pipe should be worked to its true form. A square bend may be made with less than five bending stages, but the lead is not so easily and well distributed when fewer stages are tried. At the point where the bend is to be formed the pipe may be heated to a temperature of about 220° F., with a Swedish torch, or by other means, but the back of the bend should be kept as cold as practicable. The usual plan when pulling up the pipe is to place the knee at the point where the bend is wanted, a piece of felt or other material being used as a protection from the heat. If the bend is near the end of the pipe the necessary leverage can be obtained by the aid of a mandril. As the

pipe is bent it will flatten considerably, and from this point either of the two following methods of procedure can be adopted. The first method is to turn the partially made bend on one side, whilst the opposite one is smartly struck with a suitable dresser to drive the lead towards the back of the bend; the opposite side is treated afterwards in the same manner. The driving in of the sides makes more room in the bend for working the dummy, but it possesses the drawback of forming a hard ridge on each side of the throat. In the second method, instead of driving the lead from the sides of the bend the throat is first worked up, and after this is done the superfluous lead is then driven from the sides as before described. In the latter method of procedure there is less space when beginning to dummy up the throat, but there is ample space if the bend is not pulled up too much at one time. It possesses one advantage in that hard ridges are less likely to be formed.

When dressing the material towards the back of a bend there is a tendency for the latter to straighten out, and this is especially pronounced when the bend being formed is near the end of a pipe. The straightening of the bend, however, should be prevented as far as possible so as to avoid unnecessary labour. At each stage after the bend is dummied into shape a bobbin should be passed through it, to remove any irregularities and to make the bend of uniform bore. Bobbins are passed round bends by applying force either at the front or behind them.

To drive a bobbin through a bend a metal weight is caused to strike it; the weight is made secure in the middle of a strong rope, and one end of the latter is passed through a central hole in the bobbin; the weight is then drawn forwards and backwards so as to sharply strike the bobbin. Two persons are necessary to operate the weight, as the rope must be kept fairly taut or the weight is liable to knock against and disfigure the bend.

When force is applied at the front of a bobbin no weight is used, but the bobbin is either simply jerked along a little at a time, by twisting the rope round a hammer shaft or

other tool, so as not to bruise the hand, or it is drawn round the bend by a steady pull, the necessary power being obtained by the aid of a suitable winch. As regards the best shape of a bobbin for drawing through pipes, it should resemble that of a pear in order to offer the minimum resistance against the sides of the pipes. In this case the hole in a bobbin is made in a lateral direction near the front, so as to enable both ends of the rope to be pulled in the same direction when drawing a bobbin through a pipe.

Driving Weights for bobbins are often made of plumbers' solder, and these answer fairly well and are easily obtained. Lead, of course, is too soft when used alone for weights. Brass weights may also be obtained, and some are provided with leather washers in order to protect the sides of the bends when being used.

Dummies.—To form dummies, solder ends are often cast on steel rods and Malacca canes. Canes are suitable for straight dummies up to about 2 feet in length, but for greater lengths, and where the ends require to be bent, steel rods of $\frac{3}{8}$ inch to $\frac{1}{2}$ inch diameter are used. The handles of very long dummies should be fairly rigid, and may be a little thicker than the sizes given. On each steel rod two ends are usually cast, one serving as a handle when the other end is in use. Double ends also reduce the number of separate dummies for a piece of work, as these may be bent to different pitches and also differ a little in shape. A good general form for dummies is that of an egg, but this can be modified a little as experience deems necessary.

Working Drawings.—When making offsets and bends much time would often be saved if full-sized working drawings were made, either on the workshop bench or on the floor. If, for example, a pipe requires to be bent to form an offset with angles as in Fig. 57, a full size and accurate drawing should first be made, and the pipe can then be bent to the drawing.

With a chalk line or straight-edge set off the vertical lines AB, whose distance apart is equal to the external diameter of the pipe; next set off the distance between lines AC equal to the offset required, and make lines CD parallel

with those of AB. From F, or other suitable point, set off the angle of 120° with a large protractor and produce FH. Make GL parallel with FH, and the lines the same distance apart as AB. Draw curves to complete the offset. The last bend may now be made. From M, or other point, draw MO

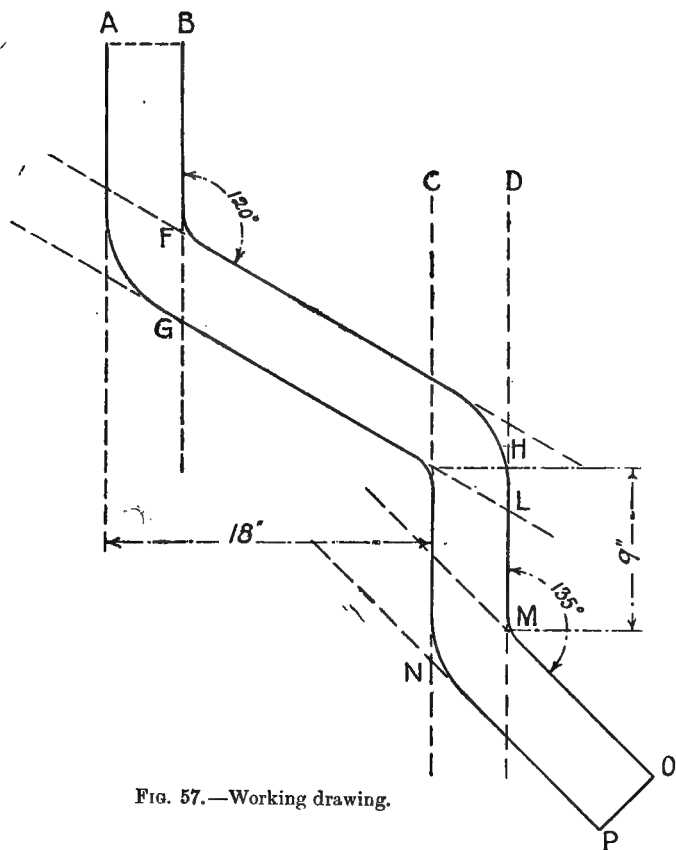


FIG. 57.—Working drawing.

so that DMO makes an angle of 135° ; draw NP parallel with MO, and complete the curves as before. The pipe can now be bent to the drawing, and when finished the plumber would be sure that it would fit its intended place. By the use of working drawings pipes can be cut to exact lengths, and the ends prepared on the bench ready for jointing in position

Development of Elbow Pipes.—Occasionally, in order to test a candidate with regard to his geometrical knowledge, Examiners of Plumbers' Work require a development of an elbow to be made. Suppose, for example, the development of an elbow similar to Fig. 58 is required. First draw to a suitable scale, or full size if required, a section of the elbow, giving it a pitch of $112\frac{1}{2}^{\circ}$. Immediately over the

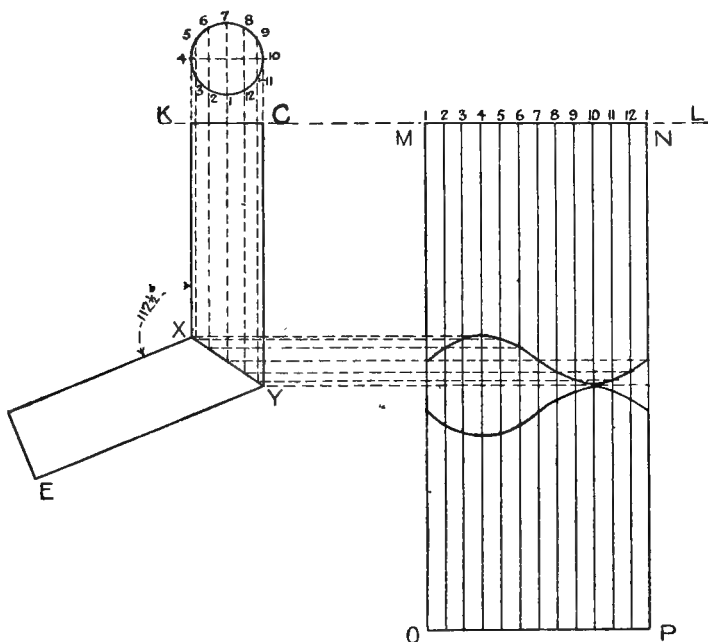


FIG. 58.—Method of obtaining shape of lead to make an elbow pipe.

vertical section of the pipe draw a plan, and divide the circumference into any given number of equal parts exceeding six; the more parts into which the circumference is divided the better the development will be. In the case under consideration the circumference is divided into 12 parts. To do this, first divide the circle into quadrants, and from the points say 1, 4, 7, and 10, with the same radius as that of the circle, describe curves to cut the circumference. Number as shown. From the points obtained drop lines

parallel with the sides of the pipe to intersect with XY, Fig. 58. On the horizontal line KL transfer the numbers 1, 2, 3, 4, etc., from the plan; make them the same distance apart, and drop perpendiculars equal in length to CYE, which represents the longest dimension of the elbow. From the intersections of the vertical lines with XY draw dotted lines parallel with KL across the verticals in MNPOM. Where the dotted lines from XY cut like numbers in MNPOM

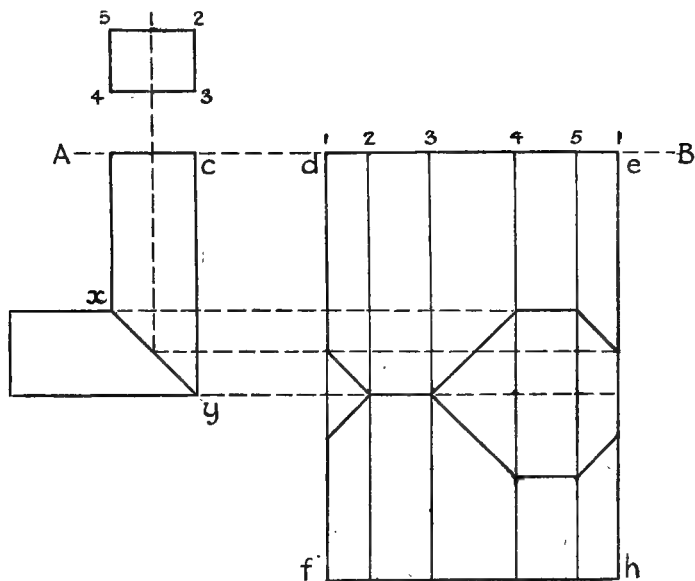


FIG. 59.—Method of obtaining shape of lead for making an elbow of rectangular section.

those are points in the development of the angle. It will be observed, upon reference to the plan in Fig. 58, that points 1 and 7 represent opposite sides of the pipes, and therefore the lines 1 and 7 in MNPOM are of equal length. This applies also to other points on the plan, such as 2 and 6, 3 and 5, etc. By connecting the points by freehand the upper curved line in MNPOM is formed, and represents the development of one half the angle. The lower curved line is drawn after plotting the distances from the upper to the lower side of the centre line. The space

between the curved lines is that which requires to be cut away in order to form the elbow required. The order of numbering the plan should be governed by the position of the joint, and in Fig. 58 the joint is shown to be in the centre of one side.

The development of an elbow for a rectangular pipe is given in Fig. 59. Number the plan of pipe as shown, starting from the point where the joint is to be made. On AB set off the sides of the pipe to agree with plan, and number in like order. Make the vertical lines in *dehfd*,

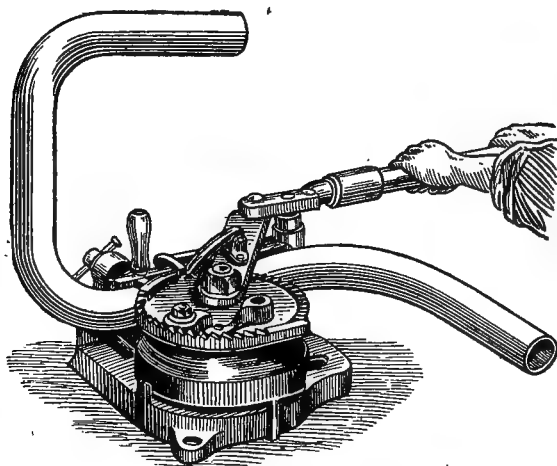


FIG. 60.—Pipe bending machine by Ed. Le Bas & Co.

Fig. 59, equal to *cyl*. From point 1 on plan drop a line parallel with the sides of pipe to cut *xy* in the section. From the three points in *xy* draw lines parallel with AB across those in *dehfd*. As before, where the dotted horizontal lines from the section cut like numbers in *dehfd*, these represent points in the development of half the angle. Join the points as shown with straight lines, and plot the distances on the other side of the centre line and complete the development.

Bending Copper Pipes.—Thin copper pipes when over $\frac{1}{2}$ inch diameter cannot readily be bent by hand without

flattening a little, unless loading is resorted to. The principal materials for loading pipes are metallic lead, sand, resin, and pitch. Lead is not often adopted as it is more troublesome to use than the other materials named.

Sand may be used for slow bends on the smaller sizes of pipes, but the ends of the pipe require to be well plugged to prevent the sand escaping when forming the bends. For making quick bends resin may be used, and it can be readily melted out when the bends have been made.

Pitch, either alone or in conjunction with resin, is largely used for bending both large and small copper pipes. It is only necessary when using the two latter materials to load the pipes short distances past the parts where the bends are required. The resin and pitch are melted for loading purposes, and a paper or other suitable plug may be used for preventing them flowing past the points required.

The bending of light copper pipes may be done in different ways, but where many bends require to be made, bending machines are desirable appliances, and much time is saved by their use. Fig. 60 illustrates a machine which is made in different sizes, and can be used for making bends on iron, brass, or copper tubes, up to three inches in diameter.

For making an occasional bend on copper pipes a hole in a plank will suffice; the sharp edges should be removed, and after loading a pipe the latter can be passed through the hole, when the bend may be gradually turned. If the pipe should flatten a little during the process, the bend may be rounded up either with a hard dresser or round-faced hammer.

Copper pipes are occasionally found to be very hard, and they require to be softened before being bent. To soften copper pipes they are frequently heated to redness and suddenly cooled. Brittleness of copper pipes is frequently due to their not being properly annealed.

CHAPTER IV

PIPE JOINTS

THE joints with which a plumber should be familiar are very numerous, as their form must necessarily vary with the different kinds of pipes, the positions in which the pipes are placed, and the purposes for which the pipes are required.

Joints for Lead Pipes.—Those chiefly used for lead pipes are: (a) Straight and branched forms of plumbers' joints; (b) Block joints; (c) Flange joints; (d) Lip joints.

Plumbers should be capable of making soldered joints in any situation, for frequently pipes are much disfigured in getting them into position, and especially so if their relative positions are greatly altered whilst the joints are being made.

All young plumbers would be well advised to avoid the use of plumbing irons, spirit-lamps, and similar appliances when learning to wipe soldered joints on the smaller sizes of pipes. To manage without their aid a plumber must be quick in the manipulation of the solder, and this is essential in order to become skilful in the art of jointing. Plumbing irons, Swedish torches and spirit-lamps, etc., are, however, very useful appliances when used in their proper place.

Preparation of Joints.—When preparing the ends of pipes for jointing, this part of the work should be neatly done. The faucet end for an underhand joint should not be opened unduly wide, and the spigot end should be slightly opened after being trimmed in order that no unnecessary retardation is caused where a joint is introduced. Each end should then be rasped to a thin edge and the tarnish or smudge applied. After the shaving is done, the prepared ends are brought together and made secure,

when the joint is ready for wiping. Fig. 61 gives three forms of plumbers' joints, those at A and B being shown partly in section and partly in elevation.

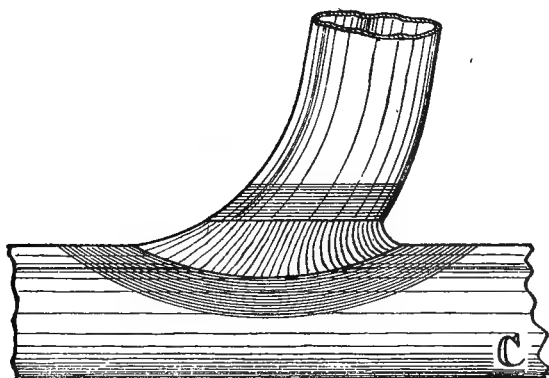
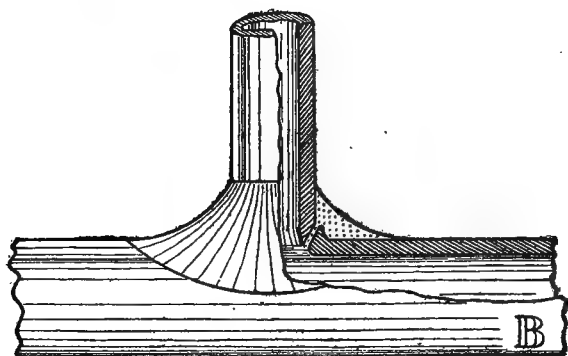
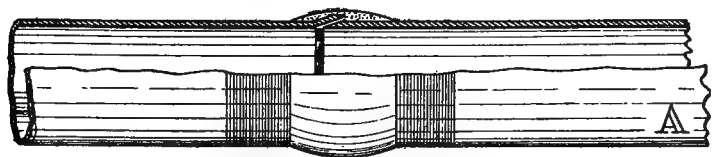


FIG. 61.—Joints for lead pipes.

For soil and waste pipes their branches should curve in the direction of flow as at C, Fig. 61. The latter form of joint

requires to be carefully prepared, or the solder will run through into the pipes when making it; or if a thick edge is left either at the front or at the side of the joint it will probably be laid bare during the jointing process.

To guard against solder getting into pipes it is a good practice, when preparing large branch joints, to smear with plumbers' black the inner surfaces of the opened part, and also the end of the branch piece for about $\frac{1}{8}$ inch on both its inner and outer surfaces. This precaution does not impair the general soundness of a branch joint, and no trouble will be caused by solder running through, provided the joint is properly prepared and is not played with too long when applying the solder.

Another precaution when preparing the spigot end to prevent solder running through the joint is, first, to neatly fit the branch piece, when a mark is made on the latter around the top edge of the opened part. The branch is then removed, and a groove cut with a saw file on the lower side of the mark. Afterwards the pipes are blacked and shaved, care being taken not to shave out the small groove in the spigot end. When the prepared branch is in position, the thin edges at the top of the opening are driven into the groove by the aid of a small hammer and blunt iron chisel.

Openings for branches should stand up evenly all round. To form a large elliptical opening in a thin lead pipe, a hole may be bored with a large gimlet or other suitable tool half an inch clear of each end of the major axis. A slot may then be formed by cutting out the strip of lead between the gimlet holes, and afterwards opened up with the aid of a heavy bent pin and small hand dummy.

Gauges.—To prepare joints on straight pipes of uniform size is a simple matter, as the ends of the pipes only require fitting together in order that the length of the shaving can be correctly proportioned on each side. For branch joints gauges are necessary where uniformity of size is desired.

Gauges are often made of sheet brass, and may take the form given in Fig. 62. It is an advantage to have two of these gauges, one for small and the other for large

branch joints. Down the centre of the gauge, Fig. 62, a number of small holes is made in which one of the points of a pair of compasses is inserted for marking off the portion to be shaved. The central point at the bottom edge is useful when making right-angled branch joints, as it can be fixed directly in the centre of the opening so as to make the scribing equal on both sides. For curved branch joints the central point is not of much service, as the gauge requires to be fixed off the centre, the exact distance away varying with the angle at which the branch joins the opened pipe. After

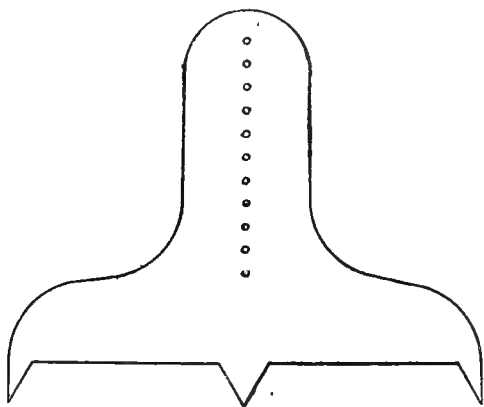


FIG. 62.—Gauge for marking branch joints.

the true position of the gauge has been obtained the scribing for the joint is effected from each side.

Methods of Supporting Joints.—The methods of staying joints for wiping purposes are very varied, and are largely governed by the sizes of the pipes, by the positions in which the joints are to be made, by the packings at disposal, and by the intelligence of the individual executing the work. In new buildings, where bricks and timber are plentiful, these are largely used for fixing on floors and other flat surfaces; where joints are made against walls near ceilings, fixing points are very useful for staying purposes. The use of strong cord and fixing points will in many cases dispense with the aid of more cumbersome things.

When staying branch joints for soil and waste pipes, more care is necessary than for thicker lead pipes, for unless the weight of the branch be also supported there may be danger of the whole falling down when getting up the wiping heat.

An old but excellent method of supporting branches in large lead pipes whilst wiping a joint is illustrated in Fig. 63. After the opened part and spigot end have been prepared, two pieces of wood about a foot in length and $1\frac{1}{4}$ inches square are placed over each other inside the pipe; upon these, two wedge pieces are fixed back to back in order to keep the spigot end from protruding too far into the opening. These packings,

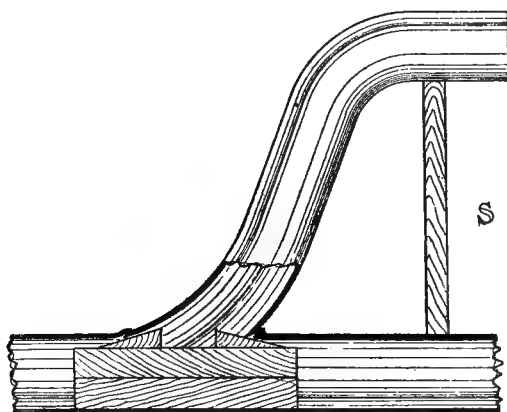


FIG. 63.—Method of supporting pipe whilst jointing.

of course, are placed in position before the branch is inserted. The weight of the branch may be simply supported as at S, Fig. 63, or in any other suitable manner. To secure the branch, a piece of cord may be passed round the bend, with the ends fastened down to the bench on opposite sides of the branch. Should a branch be a long one, the wood fixings may be left in position whilst it is carried from the bench and fixed in its place. The packings inside the branch may be readily displaced by either a piece of wood or a length of iron tube. In the case of vertical pipes the packings may be dislodged by a plumb-bob, but access will be necessary for regaining the packings. The object of having

packings for the inside of branch joints in four parts, instead of in three, is to allow them to pass more readily round a bend.

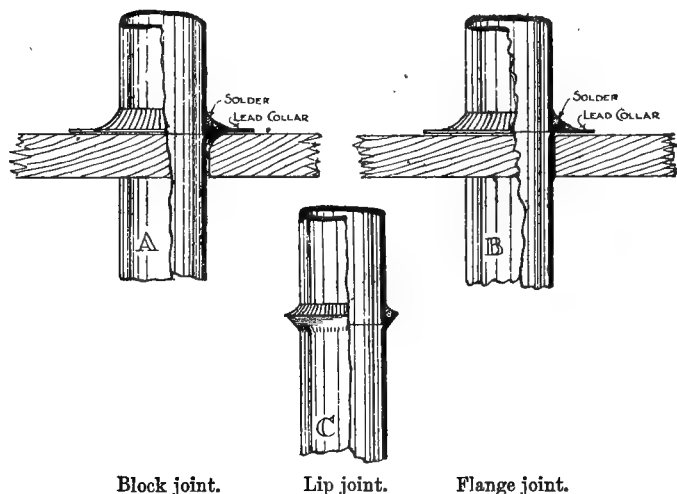
Many methods are in use for holding brasswork to lead pipes whilst the joints are being made. Several forms of metal clamps and fixings may be obtained for this purpose, and some are very useful appliances. The tail-pieces of unions and taps, etc., are not difficult to hold during the process of jointing. When a brass tap is branched into a lead pipe, one method of staying the former whilst the joint is being made is to file a groove near to the tail end and to drive the lead into it from around the edge of the opened part. A second method is to form two or three coarse threads with small stocks and dies on the tail end of a tap, and to make the hole in the pipe suitable in size for the tap to be screwed into it. This makes a simple and substantial fixing, especially if the lead round the edge of the opening is well worked up and is also driven into the threads. Another method for holding a tap whilst making a joint is to fuse or "burn" the edges of the lead to the brasswork with a well-faced soldering bolt, which is heated to dull redness. The lead unites with the tinning on the brasswork, and this most readily occurs when the brasswork is well heated just prior to "burning on," as it is termed. The worst feature of this method is that the soldering bolt must be frequently re-faced. It, however, securely holds the brasswork when the "burning" is properly done, and it is not liable to give way if the joint is wiped in a reasonable time. To "burn on" it is important that the soldering bolt has a good face, otherwise this form of fixing is indifferently performed.

For fixing brass tail-pieces on the ends of pipes "burning on" is often very convenient, especially for the smaller sizes of fittings. If well done, it resembles a narrow copper-bolt joint, excepting that neither a strip of lead nor solder is used. Resin, however, is used as a flux.

Another convenient method for supporting tail-pieces is by using a number of narrow wood strips. These can be pushed through the tail-pieces into the pipe, and a reliable and simple fixing thus obtained.

When wiping joints, some discretion should be exercised with regard to the quantity of solder used ; it is clearly obvious that for soil and waste pipes the joints should be lightly formed, when compared with those for water pipes which are required to withstand more or less considerable pressure.

Many plumbers experience difficulty in making a good shaped light joint of moderate length, although they have no apparent difficulty in making a heavy joint. As a rule, the reason why many are unable to wipe light joints is owing to the use of thin, flabby cloths.



Block joint.

Lip joint.

Flange joint.

FIG. 64.

To make light joints of moderate length a fairly stiff cloth is essential, and many good joint makers, in order to impart the necessary stiffness, insert a thin piece of zinc in the centre of their cloths. Others introduce a thin layer of cardboard for the same purpose. These stiffened cloths are used chiefly for shaping the larger sizes of joints, more pliable ones being used for getting up the heat.

Block Joint.—For lead soil pipes which are fixed in recesses inside buildings the block joint is very suitable, as it forms both a joint and a good fixing for the pipe. The upper edge of the hole in the wood block should be well

rounded off as in A, Fig. 64. A lead collar is placed directly upon the wood support, and the faucet end before being opened should be cut so as to stand not more than $\frac{5}{8}$ inch clear of the top of the support. When the end is opened with the tanpin, a space should be left between the lip and lead collar so as to allow the solder to flow under the lip. The lead collar would, of course, be shaped, and the preparation for soldering done, before a length of pipe is placed in position.

Flange Joint.—At B, Fig. 64, a flange joint is shown; this is inferior to the block joint, although it is made very much in the same manner. In the flange joint, the sharp aris only is taken off the woodwork, a lead collar being used as before, with the faucet end flanged right over on to the collar.

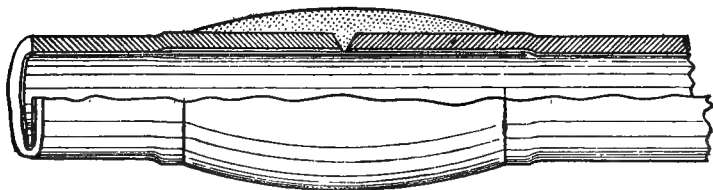


FIG. 65.—Method of jointing tin-lined lead pipe.

Lip Joint.—The lip joint C, Fig. 64, is more suitable for gas pipes than for either water-pipe or waste-pipe work. In certain districts where inferior work is done the lip joint is often used, on account of its cheapness, for joining brass connections to overflow pipes, to lead traps, to hot-water service pipes, and to other low pressure pipes.

There are circumstances, however, under which a wiped joint is no stronger than a lip joint; in fact the latter may be much the stronger of the two. This may occur when a very short brass tail-piece is joined to a lead pipe with an underhand joint. Under such conditions the joint is principally formed on the pipe, with the result that the end of the pipe, which has been reduced in substance, is nearly laid bare.

Joints for Tin-Lined Lead Pipes.—When solder is used, the joints for these pipes are not prepared in the same manner as those for lead pipes, as the heat of the solder

would melt the tin linings in the neighbourhood of the joints, lay bare the lead to the action of the water, and the latter in its passage through the pipes may be considerably retarded.

To avoid destroying the tin linings thin brass ferrules are sometimes used, as in Fig. 65. The ends of the pipes may be slightly expanded by means of a steel pin specially made for the purpose, and the ferrule when inserted should be tight fitting; the joint is then wiped with plumbers' solder in the usual way. During the process of wiping there is still the liability of destroying a little of the lining beyond the ends of the ferrule, although this may be avoided to a

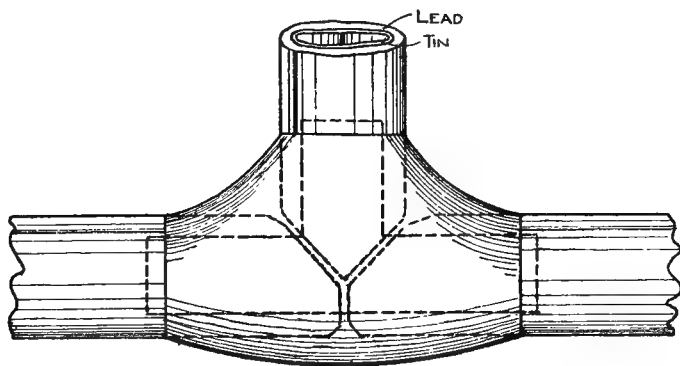


FIG. 66.—Branch joint for tin-lined lead pipe.

certain extent by the use of longer ferrules than that shown in Fig. 65.

A method of preparing a branch joint for tin-lined lead pipes is indicated in Fig. 66. It is, however, troublesome to prepare, for it is necessary to cut in two the pipe at the point of junction and to mitre the ends as shown. Each of the three ends is slightly expanded as before described, and when blacked and shaved, a brass tee-piece is inserted, and a joint wiped over the ends, so as to form a combined branch and underhand joint. The dotted lines in Fig. 66 represent the brass tee-piece.

Another method of joining tin-lined lead pipes is illustrated in Figs. 67 and 68. In Fig. 67 a simple form of union coupling is shown, and the ends of the pipes are simply

flanged over and brought together by means of the screwed cap and ferrule. Fig. 68 gives a special gun-metal fitting, the ends of the pipes being flanged and treated in a similar manner to that shown in Fig. 67.

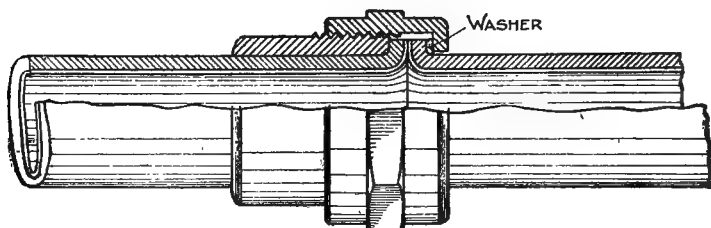


FIG. 67.—Joint for tin-lined lead pipes.

The latter is the better method of joining tin-lined lead pipes, but the special fittings make such pipes expensive.

Burnt Joints for Lead Pipes.—Where lead pipes are used for conveying acids, burnt joints require to be made, as ordinary soldered joints are more or less rapidly destroyed.

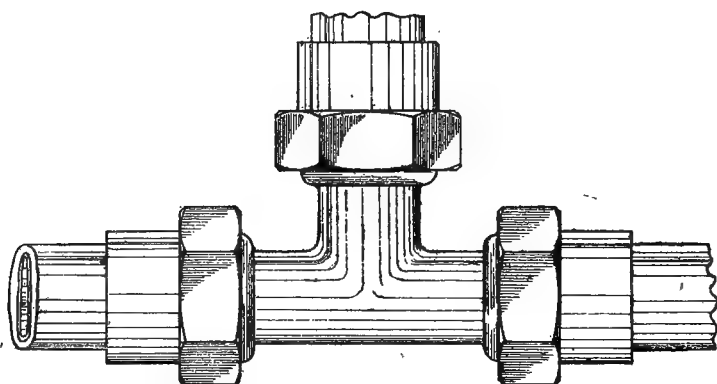


FIG. 68.—Branch joint for tin-lined lead pipes.

Burnt joints are used to a limited extent for both lead soil and waste pipes, and several forms of these joints are given in Fig. 69. At A an ordinary form of lip joint is shown, and the only difference between it and a soldered one is that a strip of lead is used in lieu of solder when making the joint. Where a horizontal pipe may be turned during joint-

ing, the form B, Fig. 69, can be adopted. C and D give two different branch joints; the one at C may be made when the branch piece is in the position shown. D is a much

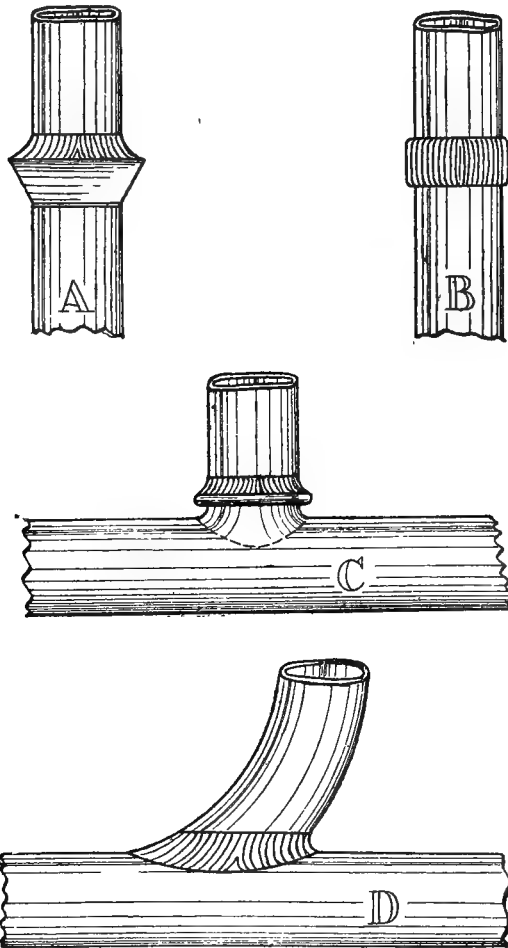


FIG. 69.—Forms of burnt joints.

stronger type of joint, but to make it the whole branch must be free, so that it can be turned on either side whilst the lead is built up upon the joint.

With regard to the merits and drawbacks of burnt joints for pipes in general work, the latter far outweigh the former.

The chief disadvantages of burnt joints for lead pipes are: the time occupied in making them; the limited positions in which they can be made; and the amount of space necessary, as every part of the joint must be readily accessible when being formed.

Joints for Copper Pipes.—The standard method of jointing copper pipes, which are used either for hot-water services or for heating apparatus, is by means of screwed joints. In the British standard tables coarse threads are used, the walls being sufficiently thick so as to dispense with the soldering of the joints. There are three standard tables. Table I. provides for low working pressures up to 50 lb. per sq. inch; Table II. for medium pressures up to 125 lb. per sq. inch; and Table III. for high pressure work up to 200 lb. per sq. inch. The principal difference in the dimensions of the tables is in the thickness of the tubes and in the pitch of the threads.

Screwed and soldered joints for *light* copper pipes, which only permit of fine threads being cut, are not suitable for either hot-water services or for heating apparatus. Such joints are not durable as a rule, chiefly owing to galvanic action, which corrodes the soldered joints and causes the latter to leak.

It may be asked that if fine threads and soldered joints on light copper pipes are liable to fail through galvanic action, why are not the joints on the standard tubes if these are also soldered? The reason is not far to seek. With comparatively strong pipes and fittings, the joints can be made water-tight without the use of solder, the latter serving more or less as a mere safeguard against leakage. With thin copper pipes and fine threads, even assuming the joints at the outset did not depend for their water-tightness upon the soldering, it is scarcely to be expected that they will remain long in that condition, owing to the varying strains to which the joints are subjected by fluctuations of temperature. As soon as a certain class of water finds its way between the threads of the pipes and those of the fittings, and comes in contact with the solder, the latter is slowly destroyed, owing to a galvanic couple being formed.

Stronger joints on copper pipes, if soldered, may also fail through galvanic action, provided they were imperfectly made, or depended for their soundness upon the soldering. When, however, the coarser threads are used, as in the case of the British standard tables, the soldering of the joints is not essential, and it is not usually carried out.

Very light copper tubes, however, may be safely employed for hot-water services and similar uses, provided suitable joints are adopted. The failure in the past of thin copper pipes was due to the weakness of the *joints* and not to the *thinness* of the tubes themselves.

Compression-Joints.—The most suitable joints for very thin copper tubes are those where their ends are brought

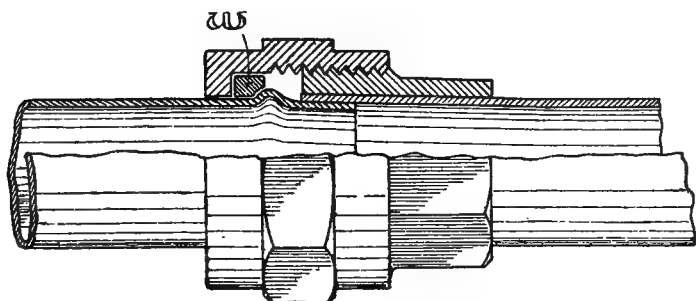


FIG. 70.—Leighs' compression-joint for light copper pipes.

together and made air and water-tight by compression. Compression-joints have been used by heating engineers on the Continent of Europe for many years, and more recently a few good forms of compression-joints have been patented in Great Britain. The construction of one of these joints is clearly shown in Fig. 70. The ends of the pipes to be joined are prepared by expanding one end, whilst the other has a beaded shoulder formed in it. By means of a screwed cap and sleeve piece one end is forced inside the other, and a substantial joint is formed in which no jointing material is required, the soundness of the joint relying upon the closeness of the metal surfaces. A washer W is placed behind the raised bead to prevent the latter being cut or chafed when screwing up the joint.

For preparing the pipe ends two machines are necessary, one for making the bead and the other for expanding the ends. Special fittings are also required, such as tees, elbows, etc.; these have their ends coned in order to receive the tubes upon which the beaded shoulders are formed. With regard to the soundness and strength of the compression-joint shown, it is stated by the Patentees that a $1\frac{1}{4}$ -inch seamless copper tube of 20 I.W.G., when connected with various fittings, proved tight with an internal pressure of 700 lb. per sq. inch, and that a tensile force of $8\frac{1}{2}$ tons was necessary to pull a joint apart.

Iron Pipe Joints.—Wrought-iron pipes are usually joined with screwed socketed joints, whilst cast-iron pipes are

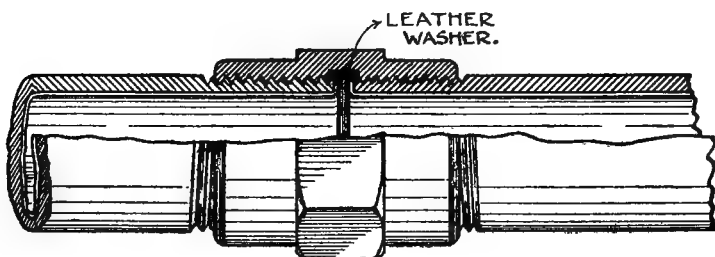


FIG. 71.—Left and right screwed joint for "Health" water pipe.

generally jointed either by flanges which are brought together with iron bolts or by a spigot and socket form of joint.

The method of making the joints, and the jointing materials employed, depend chiefly upon the purpose for which the pipes are required. For *screwed joints* on wrought-iron pipes a mixture of red and white lead mixed to the consistency of thick paint is frequently used. It is usually necessary, however, in the case of pipes which convey water, air, or steam under pressure, to wrap fine hemp between the threads on the ends of the pipes after painting them. *Pipe-joint* compounds may also be obtained for making joints, and these preparations are usually superior and more cleanly in use than mixtures of red and white lead.

Fig. 71 shows a screwed joint for the "*Health*" water pipe, which consists of a wrought iron tube with a tin lining. In the centre of each socket a space is provided in which a

leather washer is loosely placed. Each joint is made with right and left-hand threads, so that each socket forms a union coupling. When preparing the pipe ends the tin lining is left a little longer than the iron tube, this being afterwards flanged over the ends. No other jointing material is required, for when a socket is screwed up the ends of the pipes are brought to press evenly against the leather washer.

Special fittings are necessary in connection with the "health" water pipe, and these are supplied by the manufacturers of the pipe.

The joint used in connection with *high pressure* heating apparatus is illustrated in Fig. 72. This is also a left and right screwed joint, but the pitch of the threads is less than that of the "health" water pipe. The sockets are very

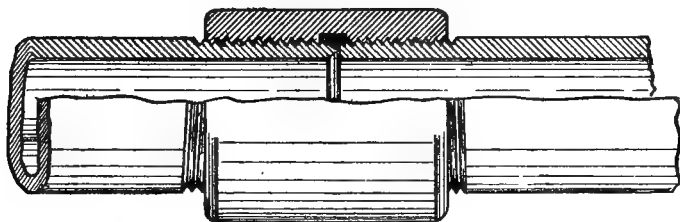


FIG. 72.—Left and right screwed joint for small bore heating apparatus.

strong, and cavities are provided at their centres where the pipe ends meet. Special screwing tackle is necessary for high pressure joints, as one pipe end is coned to form a sharp edge, whilst the other is prepared with a true flat surface. The ends are brought together with the aid of powerful pipe wrenches, so that the sharp edge of the one cuts into the flat face of the other. No jointing material of any description is used, metallic contact being responsible for the soundness of the joint.

For cast-iron pipes the *spigot and socket* class of joint is the most common. In Fig. 73 the general form of joint for iron waste, soil, and drain pipes is shown. Several strands of tarred-yarn are first inserted in the socket, and the upper $1\frac{1}{4}$ inches of depth run full of molten lead.

To run joints properly when in horizontal situations, clay

bands or their equivalent are essential. The bands are placed around the sockets so as to prevent the lead escaping when pouring it in; after the joints are made, the cooling lead contracts and leaves a small space between it and the surfaces of the pipes. It is the usual practice to free the edge of the lead from the surface of the pipe with a chisel and hammer, when the joint is made sound by well caulking it.

Frequently the joints on soil pipes are indifferently made, owing to the rope-yarn being insufficiently staved. The result of this is that the metallic lead is driven into the sockets instead of being finished flush with their top edges.

"Lead Wool" and **"Ribbon Lead."**—Instead of making the joints of iron soil and drain pipes with molten lead, "lead wool" may often be utilised with advantage. This material

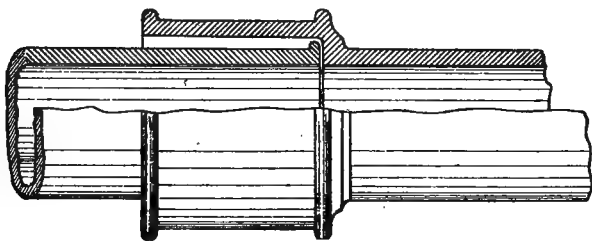


FIG. 73.—Spigot and socket joint for cast-iron pipes.

takes the form of thin threads of metallic lead, which are formed into strands for inserting into the sockets of pipes. The joints are partly made in the usual way by first introducing tarred yarn, the "lead wool" being used for the upper inch of the joint. Both the yarn and lead should be well staved when inserted into the sockets. Very substantial joints can be made with "lead wool," for when properly caulked it forms a compact mass of lead, completely filling every space of the depth to which it is inserted.

Lead is not a suitable jointing material for iron waste pipes which discharge very hot water, owing to the unequal expansion and contraction of iron and lead. For such pipes, joints made with elastic compositions on rust joints are more suitable.

Rust joints, however, are only suggested where very hot

fluids are discharged, and not for general use, for lead is both a suitable and convenient jointing material for most cases. .

Expansion Joints for Waste Pipes.—Where rust joints are deemed desirable for cast-iron waste pipes, provision is essential for the expansion and contraction of the pipes on account of the rigidity of the joints.

Bends in pipes allow a certain amount of movement to take place, and a few bends in a stack of pipes may permit of all the movement required. Where, however, a long stretch of waste pipes is rigidly fixed between two given points, and subjected to extremes of temperature, an expansion joint similar to Fig. 74 would be necessary in order for free movement to take place. The construction of the

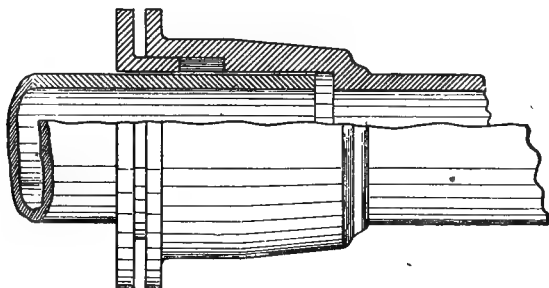


FIG. 74.—Expansion joint for cast-iron pipes.

joint is clearly shown, the packing material in the gland being asbestos or other suitable material.

The joints for iron *water mains* are much stronger than those for drains and soil pipes, as the former require to withstand more or less considerable internal pressure, and the sockets of water mains are also subjected to greater strain by the extra caulking they receive.

Joints in water mains are made by first inserting ordinary spun yarn, as tarred yarn is liable to taint the water for a considerable time. The remaining space in the socket is then filled either with molten lead or with "lead wool" or with "ribbon lead." The depth of lead required varies with the size of the pipes, with the form in which the lead is used, and with the character of the ground through which the pipes are laid,

For *water mains* of 3 inches to 6 inches diameter, if the joints are run in the ordinary manner, the minimum depth of lead for the smaller size should be 2 inches, and $2\frac{1}{4}$ inches deep for the larger size. If "lead wool" or its equivalent is used the depth of lead may be $\frac{3}{4}$ inch less in each case. The reason why less of the prepared lead may be used for making joints is due to the fact that this can be firmly caulked for the whole of its depth, whilst the lead when run, is only affected by caulking for a limited depth.

Turned and bored joints, Fig. 75, possess the advantages of dispensing with the use of yarn, which is subject to decay, and of permitting air-tight joints being made by simply smearing the prepared ends with tallow or a similar substance.

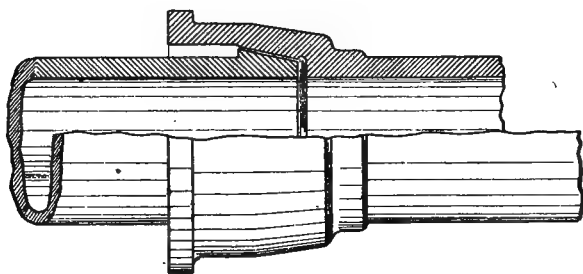


FIG. 75.—Turned and bored joint for cast-iron pipes.

In the case of pipes which carry little pressure, and where turned and bored joints are used, the angular space may be filled with portland cement or by a bituminous composition in lieu of metallic lead.

The chief drawback of turned and bored joints is their rigidity, but this, however, can be largely overcome by introducing in a line of pipes at regular intervals an ordinary spigot and socket joint. Where pipes with turned and bored joints convey liquids under pressure, metallic lead should be used as the jointing material.

Spigot and socket joints for hot-water pipes may be made in different ways. A common method of making a joint is to partly fill the annular space between the spigot and socket with tarred yarn, and to fill the remaining space with rust cement. Another method is to first insert a few rings of spun

yarn into which a suitable mixture of red and white lead has been worked; several rings of tarred yarn are afterwards inserted, and the remaining $\frac{3}{4}$ inch to 1 inch of space filled with rust cement. A third method is to first insert a couple of rings of tarred yarn, and to fill the remaining space with a mixture of red and white lead, linseed oil, chopped hemp, and gold size.

Jointing rings for flange joints, Fig. 76, largely consist of indiarubber, asbestos, metallic lead, and corrugated metal rings. Indiarubber rings are not suitable for steam pipes, but are better suited for fixing between the flanges of cold-water pipes and fittings. Rubber is also fairly durable in contact with hot water which does not exceed 180° F., but when the temperature approaches 212° F., and over, rubber gets hard and readily cracks.

Asbestos rings make good packings for steam-pipe work and where moderately high temperatures are attained.

Where metallic *lead rings* are used for flange joints, the flanges require to be truly and smoothly faced in order to prevent leakage. Lead rings are very convenient for joints which are periodically taken apart, as they can be re-used after smearing them over with grease or oil.

Corrugated metal rings are very serviceable for hot-water piping and for the flange joints on high pressure steam pipes and fittings. The corrugations form a series of concentric rings, and after the metal rings have been painted and smeared over with a jointing composition they are placed between the flanges, and the whole securely bolted together. A little fine hemp may be added to the cementing material so as to bind it. These metallic rings are usually of brass, and by squeezing the cementing material from

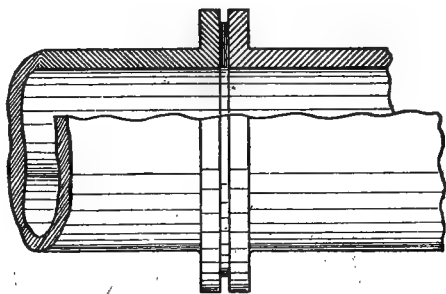


FIG. 76.—Flange joint for iron pipes.

the corrugations against the flanges a very substantial joint is made.

Expansion Joints and Bends.—Movement is commonly provided for in hot-water and steam pipes by means of expansion joints and bends. The expansion joint A, Fig. 77, is made of gun-metal, but it may be constructed for pipes with either flanged or screwed joints. It consists principally of a sleeve piece which slides through a stuffing-box of an extended socket. Expansion joints, however, are liable to leakage, and for this reason copper expansion bends are

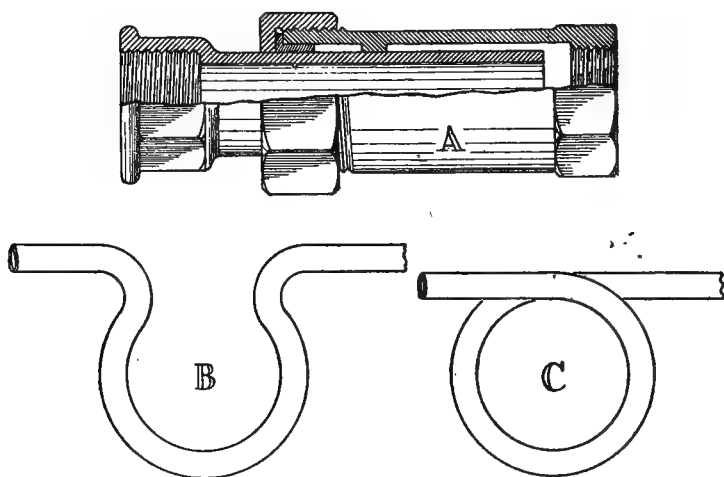


FIG. 77.—Expansion joint and expansion bends.

preferable where they can be used. When fixing expansion joints, sufficient space should be left between the socket of the sleeve piece and the stuffing-box to enable the latter to be repacked when necessary. If fixed as shown at A, there might be difficulty in removing the cap and gland so as to admit of new packing material being introduced.

Expansion bends may take different forms according to the positions of pipes. B and C, Fig. 77, give two common types of expansion bends. That at C will withstand greater strains without distortion or fracture than that at B, but its outlet and inlet ends are on different planes. Both ends of

bend B are in the same plane, and this form is generally adopted for horizontal pipes which have a limited pitch.

Wrought-iron expansion bends are not so suitable as copper ones unless formed with a larger radius. Short radius bends are too rigid, and allow the strain to be chiefly concentrated on the screwed joints.

When expansion bends are essential on vertical pipes, they may take a spiral form.

Jones' expansion joint is largely used for hot-water apparatus in horticultural buildings, and it is also suitable for other places where the head of water upon the pipes does not exceed 20 feet. This joint is made for pipes with plain ends, and consists of two loose collars, two rubber rings and an iron

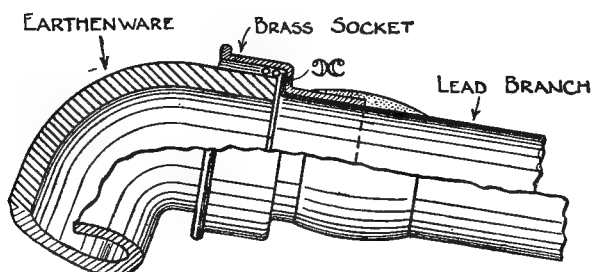


FIG. 78.—Connection between outgo of w.c. and lead branch.

band, along with two bolts and nuts. The joint is made water-tight by compressing the rubber washers, with the aid of the bolts, between the edges of the loose collar and those of the iron bands.

Joints for W.C.'s, etc.—There are several forms of patented joints for making connections between the outlets of w.c.'s and lead soil pipe branches, but one of the most common joints is that shown in Fig. 78. To the end of the lead branch pipe a brass socket is soldered, which permits of a good joint being made with the earthenware out-go of the trap. The brass socket should be slipped over the end of the pipe, and the latter turned over the inside shoulder of the socket, and be finished off as at *x*, Fig. 78. Either portland cement or an elastic composition may be used as

the jointing material after a ring of yarn has been inserted in the socket. An elastic composition is the better jointing material of the two.

Where w.c.'s are provided with lead traps, or where short pieces of lead pipe are attached to their outlets, these can be soldered directly to the lead branches.

To enable a sound joint to be made between a lead and an iron pipe, a brass sleeve piece or ferrule is first passed over the end of the lead pipe, and soldered to it as in Fig. 79. The purpose of the ferrule is to protect the lead, and to impart sufficient rigidity to enable a caulked joint to be made.

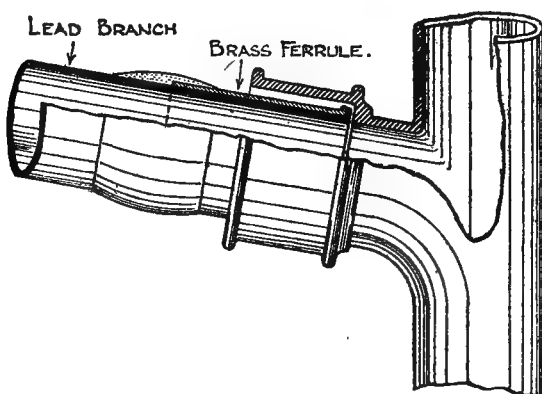


FIG. 79.—Connection between lead branch and iron junction.

When joining a lead soil pipe with an earthenware drain, it is better, on account of the width of the earthenware socket, to allow the lead pipe to protrude about half an inch or so into the bend below the edge of the ferrule, as at S, Fig. 80. This keeps the lead pipe concentric and simplifies the making of the joint.

Joints for Earthenware Drain Pipes.—The common form of joint for earthenware pipes is not one which admits of being readily made in a satisfactory manner. The chief difficulties in connection with it are: Maintaining a true alignment along the invert of the pipes, and in keeping the inside of the pipes smooth, and free from protruding matter

at the joints. Portland cement, either neat or mixed with sand, is the usual jointing material.

In Fig. 81 a couple of strands of rope-yarn, which have first been steeped in liquid cement, are pressed firmly into the socket, the remaining space being filled with cement and trowelled off as shown.

The chief drawbacks associated with rope-yarn are: it is subject to decay, and to leave cavities in the sockets where organic matter may gather. Further, unless yarn is carefully used it is liable to pass through the joints and cause stoppages in pipes.

Where solid cement joints are adopted, some form of scraper or displacer is essential to remove the surplus cement which passes into the pipes during the making of the joints. The removal of cement from the inside of pipes often results in roughening their surfaces, and in impairing the general efficiency of a drain. As any surplus cement must be removed immediately after a joint is made, and whilst it is still soft, the tendency is for the cement to run a little and to form a small ridge along the invert at each joint; there is also difficulty in obtaining a true invert, and frequently the joints form a series of steps unless something is done to prevent it.

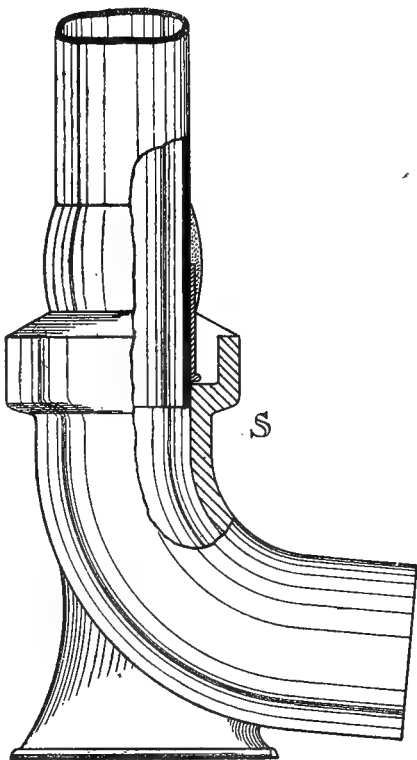


FIG. 80.—Method of connecting lead soil-pipe with a drain.

Patent Joints.—To overcome the drawbacks which accompany the use of ordinary spigot and socket joints, patented ones from time to time have been introduced. These joints possess the advantage of allowing the pipes to be easily laid, true alignments of inverts to be obtained, whilst

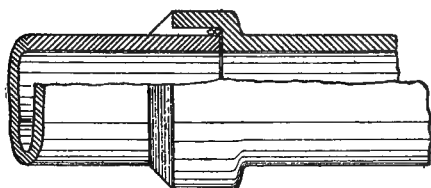


FIG. 81.—Common form of spigot and socket joint for earthenware drains.

many special joints can be made in water-logged ground without in any way affecting the jointing material. The chief disadvantage of pipes with patent joints is their higher initial cost.

In Hassall's patent joint, Fig. 82, bituminous rings are cast both at the front and back of the socket; other rings are also cast to coincide with these on the spigot end of the pipes, and the space between the rings is filled with cement in a semi-liquid state. The joint shown in Fig. 82 is known as a double lined one, the rings at *x* being omitted in the single lined form. Single lined joints admit of the use of cement in the plastic state, but liquid cement may also be used if clay bands are first placed round the sockets. Other forms of patent joints are made in which composition rings are not required, but where true inverts are obtained by means of studs in the sockets. In other cases special

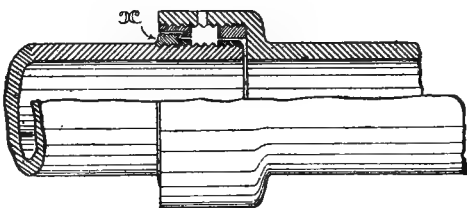


FIG. 82.—Hassall's patent joint.

forms of construction are introduced at both the spigot and at the socket ends of pipes. One of the latter type is known as the "Yarrow" joint, and is illustrated in Fig. 83. To prevent the cementing material escaping from the cavity when the joint is being run, a little plastic clay is used at both the front and back of the joint, as shown.

In Ames and Crosta's joint, Fig. 84, a little clay or

cement is used at the front and back of the sockets when running in the cement, but the true alignment of the invert is preserved by studs which are formed in the bottom of the socket.

Another form of patent joint, Fig. 85, differs again from

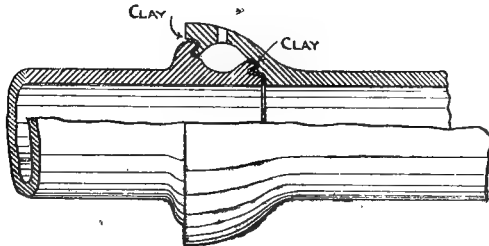


FIG. 83.—The Yarrow joint.

those already shown. In this case the inside of the socket is made sloping, in order that the spigot end, when in position, will be raised to form a true invert. For this joint the cement is intended to be used in the plastic state, and the principal feature of the joint appears to be the provision made for centering it.

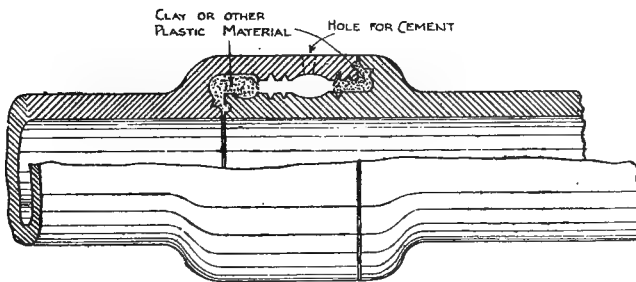


FIG. 84.—Ames and Crosta's joint.

When jointing earthenware pipes, special care is essential in the selection of the jointing material if they are to remain sound for any length of time.

The use of portland cement in the jointing of earthenware pipes has been responsible for many failures on account of the cement expanding and bursting the sockets. This is a

trouble difficult to avoid in ordinary practice, for seldom is portland cement tested as regards its suitability, except in large undertakings, where a competent clerk of works is employed. So far as earthenware drains are concerned, even assuming that reliable portland cement is used for the joints, the latter are too rigid, as any slight unevenness in the settlement of the ground results in the joints or pipes being fractured.

The easy manner in which earthenware pipes are damaged has been responsible for the introduction of iron ones where reliable drains are required.

Elastic Cement.—The difficulty associated with earthenware pipes can, however, be overcome to a great extent by using a jointing material of a slightly yielding nature. Various materials, such as resin, tallow, bituminous substances,

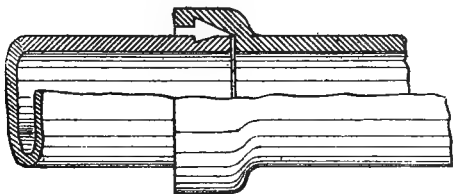


FIG. 85.—Patent joint.

sand, chalk, etc., when mixed in suitable proportions, may be used for producing yielding or elastic cements. Of whatever the cement be composed, however,

in order to be a practical success, it must not be costly, must be durable, must not creep or melt unless subjected to a high temperature, the joints must be easy to make, and the cement must not expand or contract so as to interfere with the soundness of a joint. Elastic cements may be easily made by erecting a suitable size of cauldron in which the necessary ingredients can be heated and mixed together.

As the success of a cement depends upon the ingredients used, and the proportions in which they are mixed together, experiments should be conducted on a small scale until a satisfactory mixture is produced.

The following ingredients will produce an elastic cement suitable for drain pipes :—

- 10 parts by weight of mastic asphalt.
- 5 parts „ „ „ coal-tar pitch.
- 5 parts „ „ „ fine sand.

When making the joints, a continuous stream of cement should be run into the sockets until they are filled, whilst the soundness of the joints is very much improved by smearing the socket and spigot ends with the heated composition before laying the pipes in position.

CHAPTER V

SOLDERS, FLUXES, AND LEAD BURNING

Soft Solders.—The soft solders used by plumbers are alloys, composed principally of lead and tin, and these metals are mixed in varying proportions according to the class of solder required.

Very fusible solders are commonly produced by adding bismuth to the above.

The composition and fusing temperatures of a few soft solders are as follows:—

Solder.	Composition.				Fusing Point.
	Tin.	Lead.	Bismuth.	Cadmium.	
Very fine (Wood's alloy) . . .	4	8	15	8	158° Fahr.
Very fine . . .	3	5	8	...	203° "
" " . . .	1	2	1	...	300° "
" " . . .	3	2	...	...	334° "
" " . . .	2	1	...	...	340° "
Fine for general work . . .	1	1	...	...	370° "
Fine for general work . . .	8	7	...	...	...
Wiping solder . .	1	2	...	...	441° "

The chief property of *very fine* solder is its low melting point.

Ordinary *fine* solder possesses the special property which allows it to be readily "floated" so as to form a smooth and level seam.

Excess of tin in fine solder causes the latter to have a rough appearance.

The property which makes plumbers' or wiping solder so useful for jointing purposes is the plastic state in which it remains when cooling through a certain range of temperature.

Most of the solder at the present time is not made by plumbers themselves, and unless pure pig lead can be readily procured for its manufacture it is usually better to purchase a reliable brand of solder than to make it.

Much of the sheet lead, from which solder is made in the workshop, is not produced from pure pig lead, and frequently it contains impurity which has a detrimental effect upon the solder made from it.

When making plumbers' solder, the lead and tin should be weighed out in proper proportions, and the lead should first be melted in a suitable cauldron and raised to a moderate temperature. The dross which forms on the surface of the lead should be skimmed off, and the tin then added. As soon as the tin is melted the two metals require to be thoroughly mixed, and afterwards tested by pouring to form several pats on a clean cold stone. If the upper surfaces of the pats after cooling present a white surface, with several large bright spots, the solder will be found suitable for use. A dull white surface without bright spots indicates that the solder is coarse and that more tin is necessary, whilst if the surface of the pats is covered with numerous small bright spots the solder contains too much tin.

It is essential when pouring solder into moulds to keep it well stirred, or that at the lower part of the cauldron will be deficient in tin.

Treatment of Poisoned Solder.—As impurity in solder has a very prejudicial effect upon its working qualities, every precaution should be taken to prevent brass filings and other particles of foreign matter from getting into it. Zinc is the worst form of impurity to have in solder, and this metal may be introduced in the form of brass filings, or by tinning brasswork through dipping it into the solder, or by pouring the solder over brasswork when joining the latter to lead pipes.

There are two principal methods for purifying poisoned solder. The first consists of melting the solder, when crushed

rock sulphur, or a special compound, is added ; the pot should be removed from the fire, and the sulphur or compound thoroughly mixed with the solder by stirring. The pot is afterwards replaced on the fire, and the solder slowly raised in temperature until dull redness is obtained.

During the reheating process the sulphur combines with the impurity in the solder, and these rise together with particles of lead and tin to form a thick scum on the surface of the solder. The scum or crust should be entirely removed and the solder afterwards cleared by adding a little resin. A little tin may also be necessary, but this can be readily ascertained by testing the solder.

In the second method, after the solder is melted it is poured on to a clean iron tray (a porcelain one would be preferable), and as it begins to set it is broken up into as many small particles as practicable. The poisoned solder is then covered with diluted hydrochloric acid and left submerged for about an hour. Any particles of zinc are readily acted upon by the acid, and the solder afterwards is well washed to free it from chloride of zinc. To finally clear the solder, it is reheated and a little resin added as in the first method.

Hard Solders.—Hard or brazing solders are those which require heating to redness before they can be fused ; they are used for joining the harder metals and alloys, such as steel, copper, brass, gun-metal, etc. Although brazing has not been much in request in plumbers' work, it is very probable that it will become more general in the near future, owing to the displacement of lead waste pipes in the best class of buildings by light copper pipes.

Brazed joints in connection with copper waste-pipe work would allow of more simple forms of fittings being adopted than many of those used at the present time.

Brazing may be done by heating to a suitable temperature the metals to be joined, either with a bright hot fire or with a powerful gas blow-pipe. The surfaces to be brazed are prepared by filing them clean, and the hard solder is used in a granular form with powdered borax as a flux. After the parts to be joined have been prepared, the flux

and granulated spelter are placed on the joint, and heat applied until the spelter floats round the joint, in a similar manner to that in which fine solder is used for jointing lead pipes.

When brazing brass fittings and copper pipes together some protection must be afforded the brasswork, or the latter may be fused when making the joints, as the composition of brass fittings may not differ very much from that of the spelter used.

Brasswork is readily protected from fusing by plastering it over with clay, excepting the surfaces which are to be brazed.

Gas blow-pipes are very useful and convenient for light brazing, and especially when oxygen is used in lieu of atmospheric air.

Heat of greater intensity may be obtained by the use of acetylene and oxygen.

The composition of hard solders or spelter necessarily varies according to the metals to be brazed.

Spelter.	Composition.		
	Copper.	Zinc.	Tin.
Hardest for iron and steel	2	1	...
Hard for copper, gun-metal, and hard brass .	1	1	...
Soft for soft brass	4	3	1

Fluxes.—The principal uses of fluxes when soldering are: to prevent the oxidation of the prepared surfaces so as to enable a sound joint to be made, to assist the solder to flow, and to aid in cleansing the surfaces to be soldered.

One particular flux is found to be more suitable than another when soldering certain metals, and the following gives the fluxes best suited for the metals and alloys used in plumbers' work:—

Metal or Alloy.	Flux.
Lead when coarse solder is used . . .	Tallow.
Lead when fine solder is used . . .	Tallow and resin.
Zinc (new) . . .	Chloride of zinc.
Zinc (old) . . .	Hydrochloric acid.
Brasswork and gun-metal . . .	Resin.
Tin and pewter . . .	Sweet oil.
Iron when soft solder is used . . .	Chloride of zinc or sal- ammoniac.
Iron, copper, and steel when brazed . . .	Borax.

Lead Burning.—This is a term which denotes the uniting of two or more pieces of lead by fusion, and without the aid of either a flux or alloy. The cost of jointing sheet lead by “burning” is small when compared with that of soldering, and as sheet lead can be effectively jointed by “burning,” the latter mode of jointing is rapidly gaining favour.

Lead burning is accomplished by combining two gases which produce upon ignition a hot clean flame. The mixed gases are delivered at a nozzle or nipple, and the size of the flame is adjusted and directed on the surfaces to be joined, and fused together a little at a time.

There are three different mixtures or combinations of gases used for lead burning purposes—

- (a) Pure hydrogen gas and atmospheric air.
- (b) Coal-gas and atmospheric air.
- (c) Pure hydrogen and oxygen.

When hydrogen and air are used, the former is usually generated in a machine, the latter being delivered from a container which is charged by means of a force pump.

When coal-gas and oxygen are used, the former is obtained from the nearest available gas pipe, whilst oxygen may be obtained compressed in strong steel cylinders.

Compressed hydrogen and coal-gas may also be obtained in cylinders if desired.

A complete arrangement for lead burning is shown in Fig. 86, the hydrogen generator being on the left side, and the apparatus for supplying air on the right side of the figure. For a small generator a suitable size is 10 inches

square, and the chambers A and B may be each about 1 ft. 3 in. high.

The whole of the generator should be made of lead, but when it is intended to be a portable one it will require protecting by a suitable casing as shown. The upper chamber A is made separate from the lower one, and may be removed after taking the joint J apart.

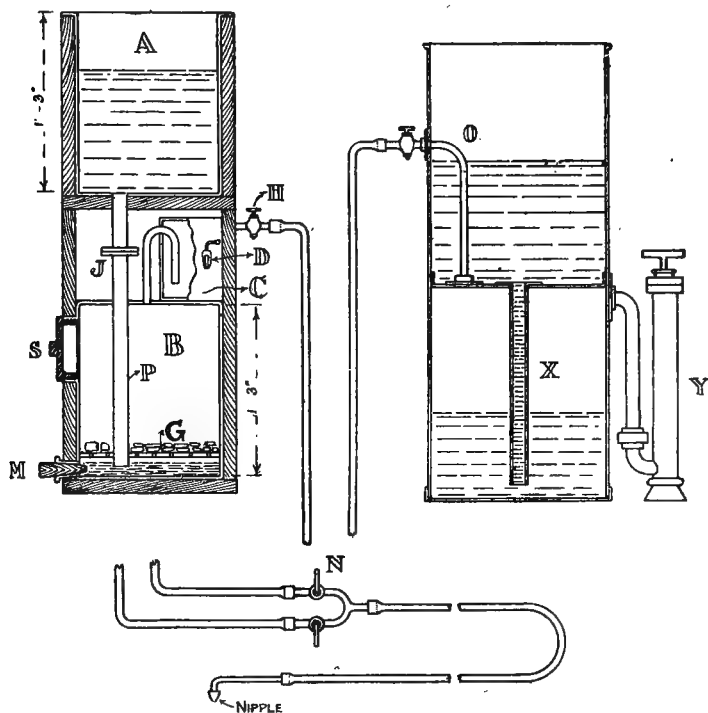


FIG. 86.—Hydrogen generator and air tank.

Between the large chambers A and B, a small compartment or safety chamber C may be provided of say 4 inches diameter. A lead grate G, which is perforated with $\frac{1}{4}$ inch holes and $1\frac{1}{2}$ inches apart, is fixed about 2 inches above the bottom of chamber B.

At S a 5 inch gun-metal screw cap is required, and a washout at M, which is closed when the machine is in use

by means of a wood plug. A pipe P of 1 inch or $1\frac{1}{4}$ inches diameter communicates with the upper and lower chambers, and the bottom of the pipe should terminate not less than 1 inch clear of under surface of the grate G. From the top of chamber B a $\frac{1}{2}$ -inch pipe is taken and turned through into the safety chamber C, and continued nearly down to the bottom as shown. A small cock D may also be fixed, so as to regulate the height of the water in the safety chamber C.

To charge a generator, a few pounds of zinc, which is broken into small pieces, are distributed over the grating G, and the screw cap S replaced and made air-tight. The cock at H is closed, and into the upper compartment A water is poured. Some of the water enters the lower chamber through pipe P, but its entry is soon prevented owing to the air in B being unable to escape. To each gallon of water about three-quarters of a pint of strong vitriol (sulphuric acid) is afterwards added, so as to well mix with the water in A. The cock H is now opened, the confined air escapes, and the diluted acid flows into B and submerges the spelter, when the generation of hydrogen begins. As soon as all air is displaced from the generator, hydrogen gas is available for burning. It is essential when charging a generator that the water and acid are added in the order described, for if the acid were first introduced an explosion would result.

The reason why pipe P dips below the grate G is to enable the production of hydrogen to be controlled. When the gas begins to accumulate and to generate pressure, it displaces the dilute acid from chamber B back into that of A until the acid is clear of the zinc, when the evolution of hydrogen is automatically stopped. At the same time the end of the pipe below G remains sealed, and waste is prevented, as the gas is unable to escape. It will thus be seen that when a generator is in use, the diluted acid in A rises and falls according to the rate at which the gas is used.

Care is necessary in the management of a generator if it is to work satisfactorily. Each day after use the spent or dilute acid should be discharged, and the generator well washed out with clean water. Instead of a wood outlet plug M, a stoneware cock may be used, but the former is more

satisfactory for a portable machine, as the latter is liable to be broken. The zinc should be broken into small pieces, as a greater surface is exposed to the action of the acid than when large pieces are used. When a generator is not regularly cleansed, sulphate of zinc begins to crystallise and to choke up the pipe P. Crystals also form on the surface of the zinc and prevent the free generation of hydrogen.

Should a generator, however, be allowed to get in such a state, the trouble can be overcome by washing it out with hot water, which dissolves the crystals formed. The purpose of the safety chamber C is to prevent the generator being damaged by explosion should a light be applied before all atmospheric air has been dislodged. Hydrogen alone cannot explode, but when mixed with a certain volume of air an explosive mixture is produced. If through ignorance or carelessness a light should be applied to the nipple before the air is removed, damage by explosion would be chiefly confined to the safety chamber, as the direct passage between it and B is broken by the water seal, owing to the gas first requiring to bubble through the water before it can be delivered to the tubes. The lead for a safety chamber should only be thin, and 4-lb. lead is suitable for the purpose.

The tank for supplying air, Fig. 86, is of simple construction, and is divided into two compartments as shown. This may be formed of galvanised sheet iron, a convenient size being 12 to 14 inches diameter, and about 3 feet in height. The height of the lower compartment should be a little less than the upper one, in order that water may not be projected from the upper chamber when the container is overcharged with air. The pipe X, Fig. 86, is made to communicate with the lower part of each compartment, so that water may be displaced from the lower to the upper compartment by means of the air-pump Y. To prevent water getting into the flexible tube and cutting off the supply of gas, the outlet pipe O may be carried above the lower chamber, and turned through the side as in Fig. 86.

For maintaining a steady pressure of air, which is essential for good burning, the water in the upper compart-

ment is often maintained at a constant level by continuous pumping.

After a generator and air container have been charged, the gases are led through rubber tubes of any convenient length to a breeches piece N, which is provided with regulating cocks. To the outlet of the breeches piece a few feet of mixing tube are joined, and to the other end of the mixing tube a brass tube is inserted on which various sizes of nipples can be screwed.

Lead burning is generally classified under four heads, according to the positions in which joints in sheet leadwork are made. These are as follows: Flat burning, horizontal burning, upright burning, and overhead burning. In flat

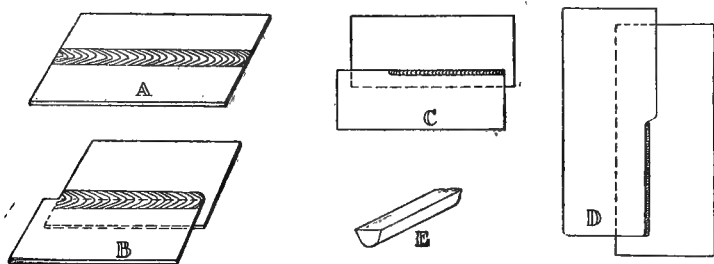


FIG. 87.—Examples of lead burning.

burning the edges to be fused may either be placed edge to edge or overlap each other, as at A and B, Fig. 87; in both cases a strip of lead is used and a raised seam formed.

Flat burning is the easiest kind of "burning," and is soon learned, but great care is necessary in the early stages, for at every point the lead must be properly fused or defects may arise which are difficult to locate.

For burning, a very hot pointed flame is required, in order that the lead may be fused at any point without first heating the surrounding surface.

Lead strips for burning are usually of the form shown at E, Fig. 87, and are cast in clean iron moulds which may be obtained at a relatively small cost.

A sample of horizontal burning is shown at C, and a lead strip is used to make the joint, provided that the edges

of the lead are thick enough to permit of it. For thin lead the overlap is simply fused with the lead behind it.

Upright burning D, Fig. 87, is much more difficult than either flat or horizontal burning, and a smaller flame is required. The edge of the overlap is fused with the lead behind it, the burning being commenced at the bottom as indicated in the figure. The joints of upright burning are much narrower than those of flat burning, and much smaller beads are formed.

Overhead burning is the most difficult to accomplish, but in ordinary plumbers' work it is very rarely if ever required. Plumbers in chemical works and similar places

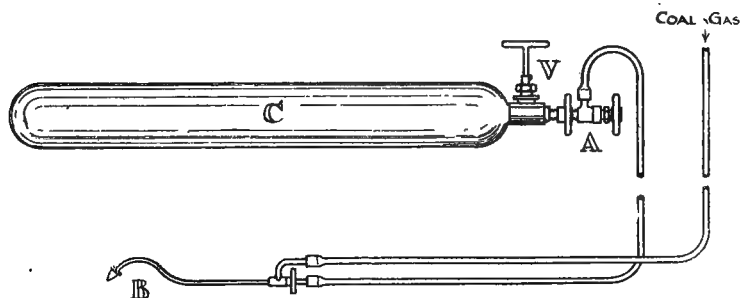


FIG. 88.—Apparatus for lead burning.

are occasionally required to do overhead burning, but not nearly so often as is generally supposed.

Where coal-gas is available, and compressed oxygen is used, the apparatus for lead burning may take the simple form given in Fig. 88.

A cylinder when fully charged with oxygen is subjected to an internal pressure of 120 atmospheres, or say 1800 lb. per sq. inch. As the gas leaves the cylinder it may be reduced in pressure with a special form of automatic regulator, and the arrangement of tubing and common nipple adopted as in Fig. 86. When, however, compressed gases are used an injector form of blow-pipe is more suitable, and the gas from the cylinder may be regulated by a simple pattern of adjustment valve.

In Fig. 88, V represents the cylinder valve; the fine

adjustment valve is indicated by A, and by it the necessary amount of oxygen is admitted to the tubes, and without subjecting them to undue pressure. As the valve A takes the place of an automatic regulator, care is necessary, however, in its manipulation. The rubber tube from the oxygen cylinder is joined with the injector side of the blow-pipe, and the oxygen and coal-gas mix in flowing towards the nipple.

A good size of cylinder for workshop use is one holding 40 cubic feet of oxygen when under the maximum pressure of 1800 lb. per sq. inch, but a 20 feet size is more suitable in other cases, as the weight of the larger cylinder is about 60 lb.

For lead burning purposes oxygen can be obtained at a reduced rate, the price of the gas being slightly less in 40-foot cylinders and over than in cylinders of smaller capacity. In country districts the cost of carriage would require to be added.

The amount of oxygen consumed varies with the kind of burning, but the average consumption may be taken at about 1 cubic foot per burner per hour.

Fig. 88 shows an apparatus which is very suitable for ordinary plumbers' use, and the initial outlay is only about one-third that for the generator and air cylinder given in Fig. 86.

Gases when compressed in cylinders are extremely useful for burning sheet leadwork on roofs, such as that on finials, stone cornices, etc., and for burning the joints of lead-lined cisterns.

A very strong rubber tube is required for the oxygen connection, as this tube is subjected to a moderate pressure.

The only preparation required for "burning" is the shaving of the surfaces, and this should be neatly done. Neither flux nor plumbers' black is required.

To line large cisterns with lead where the joints are burned, the metal should be arranged so that all the joints come on flat surfaces about $1\frac{1}{2}$ inches or so from the angles. The lead for the sides of the cisterns should be turned inwards along their bottom edges, in order that the sides and bottoms may be joined with flat burning.

For small cisterns which are easy to handle the burning may be done at their angles if desired. A strip of lead should be used wherever possible, as much stronger joints are made than where two surfaces are simply fused together.

CHAPTER VI

SANITARY FITTINGS AND ACCESSORIES

SANITARY fitting is a very comprehensive term, but in this chapter its use is confined to the larger appliances or fixtures.

Owing to the rapid advances which have taken place in sanitary science, very little space will be devoted to what are now obsolete appliances.

The general principles which should govern the construction of sanitary fixtures are as follows: (*a*) Simplicity of form, or freedom from complicated and not readily accessible parts. (*b*) They should be made of hard, durable material, with smooth and well-glazed surfaces, so as to be practically non-porous. (*c*) The design should not contain superfluous surfaces which are liable to collect dirt, and which require a lot of attention to keep them in a cleanly state. (*d*) Their outlets should be so formed that reliable and simple connections can be made with the pipes into which they discharge.

Water Closets.—The best w.c.'s at the present time are the "wash-down" and "siphonic" types. There are patterns of these, however, that are not free from structural defects, but there is no difficulty in procuring a first-class article from a good manufacturer provided a reasonable price is paid for it. Other types of w.c.'s are very inferior to those already named, and a few will be described and their principal defects noted.

An ideal w.c., besides satisfying the general conditions enumerated above, should be thoroughly cleansed with one flush of water, have a small amount of dry basin surface exposed to contamination, hold sufficient water to completely submerge all excremental matter, and be trapped in such

a manner that an effective barrier is formed to prevent the passage of drain air into the w.c. apartment.

All w.c.'s which require wood or other enclosures, with the exception of the valve closet, are now obsolete, the pedestal form taking the place of those in which basins and traps were made in separate parts:

Wash-out Type.—The wash-out w.c., Fig. 89, is a defective form of the pedestal class. The part which acts as a receiver destroys the force of the flushing water, with the result that excrement accumulates on the imperfectly flushed surfaces on the inlet side of the trap, and solid matter is also frequently left in the trap itself. In certain cases where wash-out w.c.'s have been fixed it has been essential to replace them with a better type within half a dozen years of their instalment.

Wash-down Type.—For a simple form of w.c. there is nothing better at present than the wash-down type, when well designed and supplied with an adequate flush of water. In the wash-down w.c. the full force of the flushing water is utilised to cleanse the basin and trap.

There are many different wash-down w.c.'s that vary slightly in constructional details, such as in the size and shapes of basin, size of water surface, positions of outlets, depth of water seal, and the form of flushing rim.

The size and shape of a w.c. is of considerable importance, for upon these its efficiency largely depends, and especially when flushed with a limited volume of water.

Wash-down w.c.'s with receding backs are, as a rule, objectionable, as these surfaces when fouled are not always thoroughly cleansed. The water seal in the trap of a wash-down w.c. requires to be limited, for when the depth exceeds 2 inches, considerable resistance is offered by a trap, and frequently the effective removal of excrement with one flush is uncertain. On the other hand, the water seal of a trap should not be less

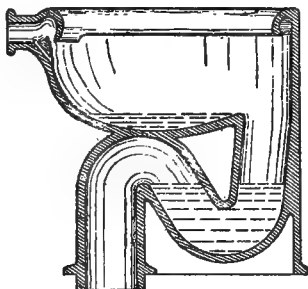


FIG. 89.—Wash-out w.c.

than 2 inches deep in order to ensure a safe barrier against the passage of contaminated air when the seal has been reduced a little by the water waving out, or by its evaporation, etc.

A large water area in a basin is always desirable, but this in turn is limited by the form the basin takes and by the volume of water used for each flush. Thus, when a water surface is comparatively large, and when a trap has a 2-inch seal, not less than three gallons of water will be required for scouring out the w.c.

A wash-down w.c. that is most easily cleansed is one that is comparatively small in size, where the water surface in the basin is small, and where the trap holds the minimum volume of water and has a small seal.

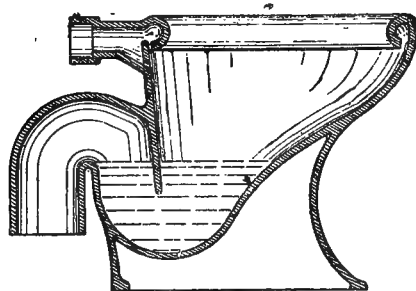


FIG. 90.—Wash-down w.c. (Doulton's "Simplicitas").

Some of the w.c.'s constructed in this manner can be flushed with two gallons of water and less, although such volumes are insufficient to cleanse the drains into which the w.c.'s discharge.

Doulton's simplicitas w.c. is illustrated in Fig. 90; the back

is constructed fairly straight, so as to minimise the risk of soiling it. The general construction of the basin is such as to limit the water area in the trap, in order that the w.c. may be flushed with two gallons of water. The outgo is well above the floor, and admits of a reliable connection being made with the branch soil pipe.

Fig. 91 gives another wash-down w.c. by the same makers. The front of the basin in this case is not curved to the same extent as in the one previously shown, and the w.c. has a larger exposed water area. This form of construction also has less surface that is liable to be fouled when compared with that of Fig. 90, but on account of the extra resistance offered by the increased capacity of the trap not less than a three-gallon flush will be required to

give satisfactory results. To the outlet of Fig. 91 is attached the firm's patent *Metallo-Keramic* joint, so that an easy and safe connection can be made with a lead soil pipe. The connecting piece consists of a short piece of lead pipe which is

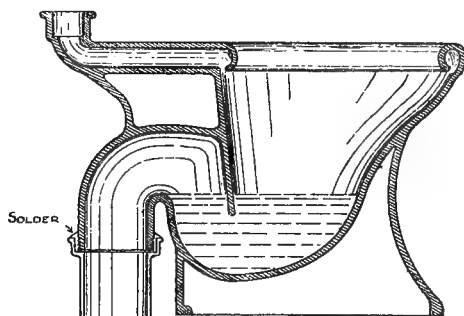


FIG. 91.—Wash-down w.c.

soldered to the outgo of the w.c. To enable a lead pipe to be soldered to the pottery ware, a metallic film is deposited on the outgo, and is afterwards fired to thoroughly fix it. The lead pipe is then soldered to the metallic film.

Shanks' "Modern" w.c., Fig. 92, differs slightly in

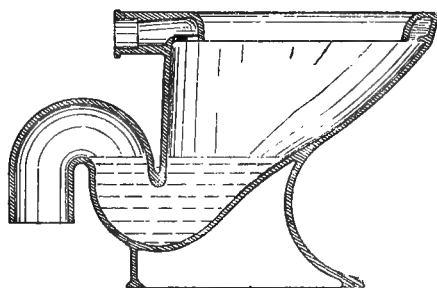


FIG. 92.—Wash-down w.c. (Shanks' "Modern.")

construction from those already shown. The back of this closet recedes a little to prevent its getting soiled, and although receding backs are not generally a success, the one shown is an exception to the rule on account of the special design of the basin and the form of flushing rim adopted.

The exposed water surface is of medium size, and the w.c. can be cleansed with a two-gallon flush, although for reasons previously stated a larger flush is desirable.

It will generally be found that wash-down w.c.'s with S traps are more easily cleansed than those with P traps, owing to the outlets of the former admitting of a freer discharge. For the poorer and cheap grades of wash-down w.c.'s those with S traps should be used wherever practicable, as those with P traps often have their outlets badly formed, and with little or no pitch.

A shape of w.c. that will permit of a $2\frac{1}{2}$ to a 3-inch seal, and yet be cleansed with a two-gallon flush, is given in Fig. 93. It will be observed that in order to satisfy these conditions both the basin and water surface are of restricted size,

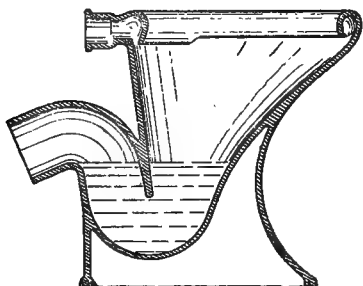


Fig. 93.—Wash-down w.c.

Flush Pipes should be as free from bends as possible, and the height of a flushing cistern need not be more than 6 feet above the flushing rim of a w.c. When flush pipes are $1\frac{1}{2}$ inches diameter, and fairly straight, a flushing head of 5 ft. 6 in.

gives very good results. Unless flush pipes are long, a greater head than 6 feet usually causes water to be projected on the floor of the apartment or on to the w.c. seat.

In situations where a flushing head is limited to about 4 feet, and a wash-down w.c. is to be fixed, care should be taken to select a small pattern or it may not be cleansed with one flush of water.

For hospital use w.c.'s are frequently constructed to enable them to be fixed clear of floors, by building into the walls corbels which form parts of the closets used. Such w.c.'s are also utilised in other public institutions where cleanliness is of paramount importance.

Combination Closets.—For situations where there is insufficient space to fix overhead cisterns the combination w.c.

may be used. The flushing rims of the basins require to be moderately large, and the outlets of the cisterns are much larger than those of overhead cisterns. On account of their silent action combination closets have often been used in lieu of those with overhead cisterns, but as regards their general efficiency they are usually inferior to the latter provided the flushing cisterns are fixed at suitable heights. The larger inlets of combination forms, and other features, do not compensate for a reasonable flushing head of the ordinary type.

Valve Closets.—The valve closet possesses some good points which are absent in a wash-down type, but the former has also failings from which the latter is free. The principal merits of valve closets are: (1) The large volume of water held up in the basins; (2) The small area of basin surface liable to be fouled; (3) The flushing power of the water in the basins when suddenly released.

The drawbacks of valve closets are: (1) Their complicated construction; (2) The mechanism in connection with them is liable to get out of order; (3) They are costly; (4) They may require to be enclosed with casings, and filth may be allowed to accumulate and remain hidden from view.

When a valve closet is fixed upon a wood floor, a lead tray or safe should be placed beneath it. The valve box and trap may either be obtained in one piece of pottery ware, and with the whole of the closet placed above the floor, or the valve box and trap may be obtained in separate parts; in the latter case the trap may be of lead and fixed beneath the floor, and the valve box may be either of cast iron, porcelain enamelled inside, or of lead.

A source of weakness with the early forms of valve closets was in connection with their overflows, but this drawback is practically overcome in modern fittings, where the overflows are open and washed out each time the closets are flushed. The valve box is made as small as possible, and provision is made for ventilating it. Fig. 94 gives a modern form of valve closet, and the trapping and general arrangement of the overflow are clearly shown. The recharging of the basin is usually controlled by some particular form of regulated valve, the water overflowing when the water-line is

reached. Valve closets are frequently adopted for ship-work, their use being essential in many cases to prevent the backwash of water.

Siphonic Closets.—Owing to the limitations of both wash-down and the best forms of valve closets, the siphonic type has been introduced. This form may not at present be the acme of perfection, yet when constructed upon sound principles it possesses most of the merits of both the valve and wash-down types.

Many siphonic closets are nearly silent in action, have a quick and powerful discharge, have large water surfaces and a minimum of fouling surface, and possess the merit of having their contents withdrawn by siphonage instead of depending upon their being dislodged by the force of the flushing water, as in the case of the wash-down type.

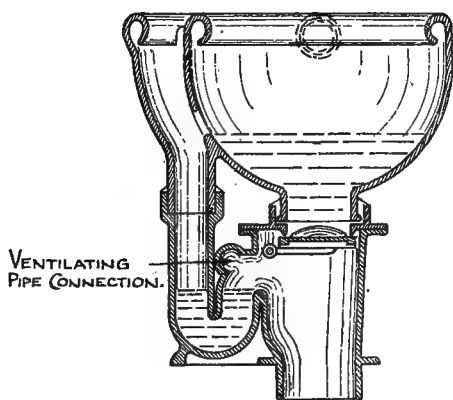


FIG. 94.—Valve w.c. where trap is fixed beneath floor.

A siphonic w.c. may also have a deeper seal than any other form.

The chief fault of siphonic w.c.'s arise through defects of construction, and not to the general principle embodied in these forms.

Various means have been devised for starting the siphonic action in these closets, such as by the introduction of jets or by peculiarities of construction, and by either the expulsion or extraction of air confined by their traps.

Many siphonic w.c.'s require special flushing cisterns to work in connection with them on account of the volume of water necessary for recharging the basins after siphonage has ceased. There are other siphonic closets with which any ordinary flushing cistern can be used, but these usually hold

much less water than the class first mentioned. The latter class are recharged with water as a rule by means of an after flush compartment which forms part of the closet itself.

For the purpose of comparison, all siphonic closets may be classified into two groups. First, those that have two traps, and second, those that only have one trap.

In the *double* trapped class, siphonage is started either by *extracting* or *displacing* air from the limb that communicates with both traps. The object is the same in either case, viz. to destroy the equilibrium of the air pressure on the water surface of the basin, and of that in the limb between the two traps.

Siphonage in the *single* trapped type is started by momentarily retarding the first outflow of water through the trap, by introducing some particular form of construction, and with or without the aid of a jet of water.

Shanks' "Levern" siphonic closet, Fig. 95, is

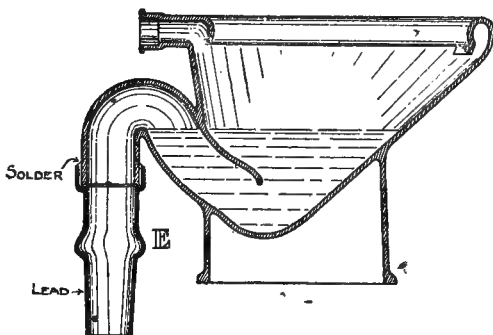


FIG. 95.—Siphonic w.c. (Shanks' "Levern").

an example of the one-trapped class. It is simple in construction, has a large water area in the basin, very little surface that is liable to be soiled, and the whole of the flushing water passes through the basin. The siphonic action is due to the enlargement E in the lead outlet pipe, and is established as follows: when the closet is flushed, the water follows the curved surface at E, and owing to the abrupt change of direction at the bottom of the enlargement the water is caused to be projected towards the centre, and to produce a momentary stoppage of the flow; the brief interval of retardation is, however, sufficient to allow the outlet leg to get fully charged, when siphonage is established, and the contents of the basin rapidly withdrawn. Provision is made

in the flushing cistern for recharging the basin with water. This design of w.c. admits of the basin being emptied of water if a pailful of slops is emptied into it, but this may be counteracted by using an anti-slop discharge attachment in connection with the closet.

Doulton's siphonic w.c., Fig. 96, represents one of the double-trapped class, and, like the one previously shown, it has a large water surface and small area that is liable to be soiled. Siphonage in this case is principally started by

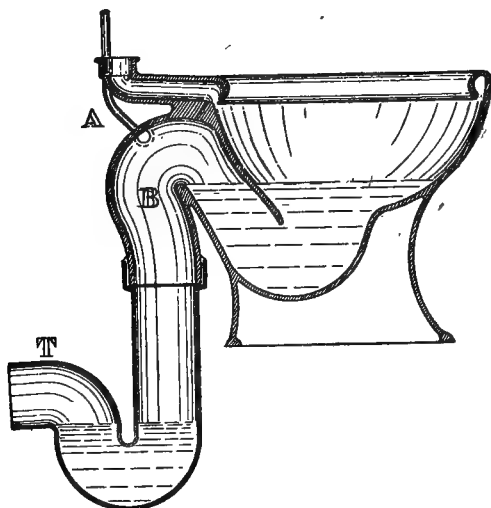


FIG. 96.—Doulton's siphonic w.c.

reducing the air pressure between the two traps by means of a small pipe which communicates with the space B and the flush pipe or cistern. It is so arranged that when the water descends in the flush pipe, the aspirating effect produced is transmitted to the limb B by the pipe A. In this manner air is withdrawn from the limb B, or rarefied to such a degree that unequal air pressures act upon the water surfaces, and cause siphonage to be established. Two traps are of course essential to confine air for this particular action, but the bottom trap also aids to a certain extent in starting siphonage by offering resistance at the outset to the escaping water, and in enabling

the limb B to be charged just prior to the siphonic action being started. The inlet of the lead trap T may be shortened when desired, so as to enable the whole of the w.c. to be above the floor.

Twyford's siphonic w.c., Fig. 97, has only one trap, and it is arranged that a portion of the flushing water passes through the outlet from point P in the form of a jet, and in the direction shown. The jet of water and the sharp elbow connection C are responsible for establishing siphonage.

Sharp elbows in soil pipes are not usually desirable, but

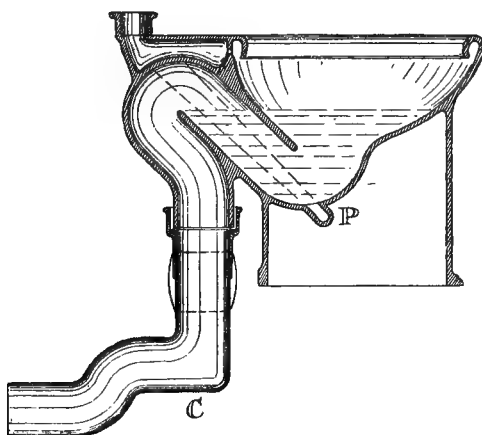


FIG. 97.—Twyford's siphonic w.c.

in this case the retardation offered by the elbow is utilised to charge the limb above point C, whilst the jet aids in removing the contents from the basin. The maximum resistance offered by the sharp elbow at C is only for a brief interval, after which siphonic action is started. This closet may also have its outlet arranged to come above the floor when required.

The siphonic w.c.'s which have been described indicate different ways in which siphonage may be established. Most makers of sanitary fixtures have produced closets of the siphonic class, and although they may differ a little in

construction, the main features do not differ much from those already shown and described.

In order that a siphonic w.c. may work properly, it is important that waste matter can be freely discharged after being admitted into the branch soil pipe; if the outflow is unduly retarded there is a possibility of the action of the closet being impaired. Branch soil pipes in connection with siphonic w.c.'s should be comparatively short and have a good pitch.

Trough Closets.—For schools, factories, workshops, etc., trough closets are frequently installed. These fixtures, however, are very objectionable, as they present large surfaces which get fouled with excrementitious matter. Although trough closets are usually provided with flushing rims, that their surfaces may be washed to a more or less extent, the effective force of the flushing water is chiefly required to scour the trough from end to end. These fixtures can only be tolerated in out-buildings, and are flushed at intervals by an automatic flushing tank.

Siphonic Latrines.—A better form of range-w.c. for fixing in out-buildings, is the siphonic latrine, or isolated trough closet, Fig. 98. Like trough closets, they are automatically flushed, and can readily be inspected to see if they are subjected to improper use. In Fig. 98 the basins are provided with flushing rims, and are connected with a horizontal pipe common to the whole range. To form the water seals, one end of the collecting pipe is turned up, so that water is made to stand at a given level in the whole range. When the flush tank discharges, siphonic action is readily established in the vertical limb B, and the contents of the basins are withdrawn. The whole of the flushing water passes through the basins, and its full force is utilised to cleanse their surfaces. The pipe A, which is joined near to the top of the bend, is carried up and turned over into the flushing tank. The purpose of this pipe is to arrest siphonage in the limb B, by allowing air to enter it, when the water in the flushing tank is lowered so as to leave the end of the pipe free. The capacity of the flush tank below the free end of pipe A only requires to be sufficient to recharge the whole of the basins with

water. The pipe A does not interfere with the siphonic action of the flushing tank, but only with that in the latrine itself.

Ranges of pedestal wash-down closets may also be fixed, and flushed by means of one or more automatic tanks, instead of each w.c. being provided with a separate cistern.

A drawback, however, that is common to automatically flushed w.c.'s is the large volume of water used, and where water is an expensive item there is often a tendency to limit its consumption and to sacrifice cleanliness.

Controlling appliances are occasionally used in conjunction

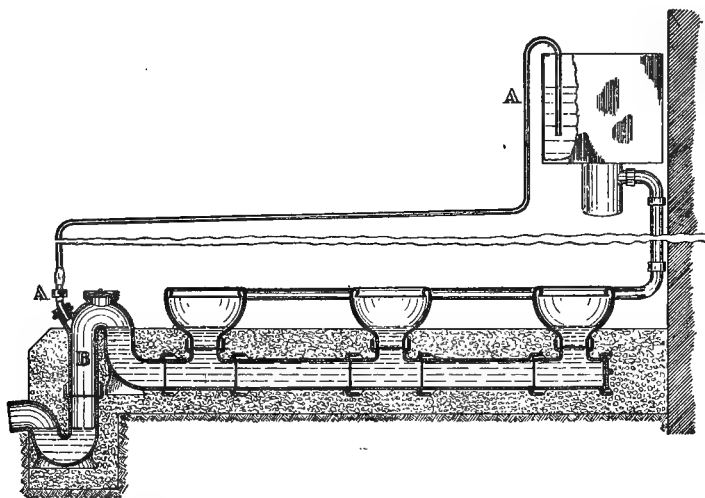


FIG. 98.—Siphonic latrine.

with siphonic latrines, with a view to reducing the consumption of water when the conveniences are not in use. These appliances, however, are not as a rule reliable, and at their best only a partial success. For large works, where an attendant is placed in charge of the sanitary conveniences, the ordinary wash-down type of closet with separate flushing cistern is the best and simplest form to adopt.

Connections of W.C.'s.—In the chapter on joints, a common and good form of connection for the outlet of a w.c. and a lead soil pipe branch is given. Flange joints which depend

upon rubber rings for their soundness do not make such reliable connections as the foregoing, and where space is limited, flange joints are difficult to make.

Special brass union couplings with ground joints are occasionally used for soil pipe connections, as these enable a lead outlet bend to be turned in any direction desired: this form of joint is better when made beneath the water-line of the trap, as the water would drip on the floor and indicate the presence of a defect if such occurred.

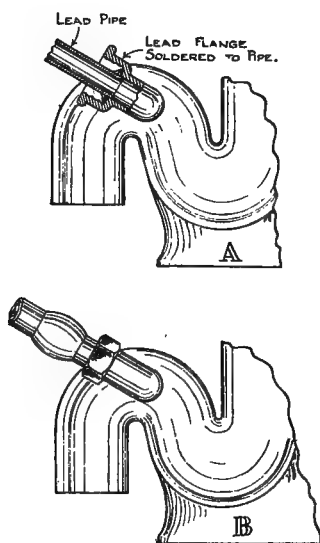


FIG. 99.—Joints for antisiphonage pipes.

Antisiphonage Pipe Connections.—A source of weakness in many closets is the connections between the antisiphonage pipes and the ventilating horns on closets. In the case of a ventilating horn being located where there is some degree of uncertainty in being able to make a reliable joint between it and the antisiphonage pipe, the best plan to adopt is to seal up the earthenware horn, and to join the antisiphonage pipe at another point. Unless a soil pipe is periodically tested, a defect at an antisiphonage pipe connection may remain undetected for an indefinite time.

If a vent horn is located at the crown of an outlet bend of a w.c. it is liable to be choked and rendered useless; moreover, if the flush pipe also joins with a horizontal connection at the back of a closet, the two joints usually come too close together to admit of their being properly made.

At A, Fig. 99, an antisiphonage pipe is shown which is joined with a ventilating horn at the side of the outgo of a w.c.; this arrangement keeps the antisiphonage pipe clear of the flush pipe, and admits of the joint being more readily made. A suitable jointing material

is a mixture of red and white lead, linseed oil, and a little hemp.

A special form of connection is given at B, Fig. 99, where the lead antisiphonage pipe is attached with a wiped joint to a brass union, which in turn is connected with the pottery ventilating horn; these union connections usually have ground faces which enable the joints to be readily made. There are many places, however, where a joint like B, Fig. 99, would be unsuitable on account of the space it occupies, but where an antisiphonage pipe may pass directly through a wall at the back of a w.c. such a joint could easily be used.

Another antisiphonage pipe connection is illustrated in Fig. 100. Here it is formed in the brass socket to which the outgo of the w.c. is joined. This latter arrangement, of course, can only be adopted where the pottery outgo terminates well above the floor.

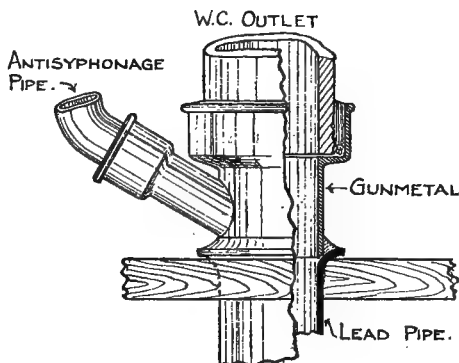


FIG. 100.—Connection between w.c. and lead pipe beneath floor.

Where practicable, one of the best methods of dealing with an antisiphonage pipe is to join it directly to the lead or iron branch instead of to the earthenware outgo of the w.c.

Flush Pipe Connections.—Although many methods have been devised for connecting a flush pipe to a w.c., a strong rubber cone will generally be found to be satisfactory where the joint takes a horizontal form. Rubber cones are comparatively cheap, and permit of reliable connections being made in confined situations, whilst many patented connections take up too much space. Thin rubber cones should not be used, as they are weak and are soon destroyed.

Where the inlet to a flushing rim is in a vertical position, a good joint may be made by first inserting into the annular cavity

between the flush pipe and socket a little hemp, and afterwards filling the remaining space with a mixture of molten resin and tallow; a little brickdust may also be added to increase the soundness of the joint. Molten sulphur also makes a good joint. A vertical connection is preferable to a horizontal one.

Flushing Cisterns for W.C.'s.—The object of a flushing cistern is not only to regulate the volume of water used per flush, but also to reduce the risk of polluting the water supply, by eliminating a direct connection between the water service pipe and a w.c. Flushing cisterns are also designed to prevent waste of water.

There are many kinds of flushing cisterns, but they may

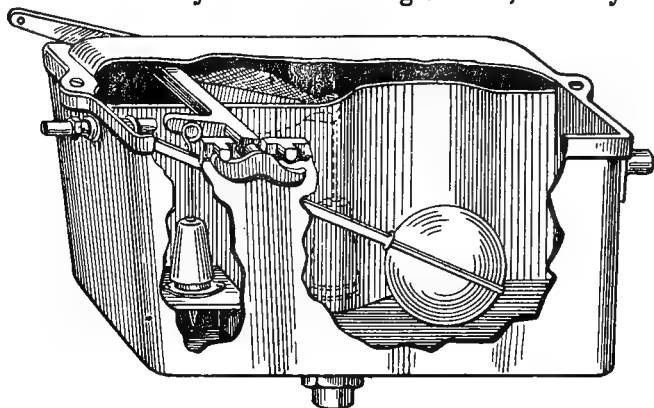


FIG. 101.—Nicholl's and Clarke's double valve flushing cistern.

be divided into the following orders: (1) Single valve cisterns; (2) Double valve cisterns; (3) Valve and siphon cisterns; and (4) Waste preventing siphon cisterns.

The first and second classes of flushing cisterns are not often fixed at the present time, as they are inferior to those of the third and fourth classes. It is generally recognised that only siphon types of flushing cisterns should be used, in order that the full volume of water may be utilised each time a w.c. is flushed.

Double valve cisterns are divided into two compartments, and have a valve in each. The compartment in which the larger valve is located contains the regulation flush, and the valves are so arranged that when one is closed the other will

be open. The general arrangement of these cisterns is clearly shown in Fig. 101.

A valve and siphon cistern is given in Fig. 102, but unless the lever is let go after the discharge has started the flush may not be as effective as it should be.

Occasionally it will be found that when water flows freely into a flushing cistern the siphonic action is not properly broken at the end of the flush, but that continuous siphonage occurs, the water being withdrawn from the cistern as quickly as it enters it. To effectively break siphonic action it is essential that air enters the siphon at the end of each discharge.

In the siphon of Fig. 102, a small hole is made at the top of the dome, just sufficient in size to break the siphonage at the end of the flush, but not large enough to interfere with the effective working of the siphon. When the dome of a siphon is of iron there is always the possibility of a small

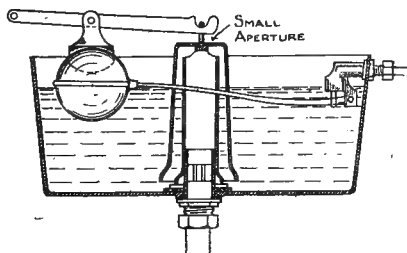


Fig. 102.—Siphon-flushing cistern.

aperture getting choked with rust, and causing the siphon to be somewhat erratic in its action. This may, however, be obviated to a great extent by drilling a hole in the iron dome and inserting a small brass plug which has previously been pierced.

The form of cistern Fig. 102 is not what can be called a waste preventer in the strictest sense of the term, but it is nevertheless a fairly good type of cistern, and will satisfy the requirements of many Water Companies.

A real waste-preventing cistern is one which is so designed that water cannot continuously escape through a flush pipe even though irregular practices be resorted to, such as the fastening down of the cistern pull, or by the holding of the outlet valve clear of its seating in any other way, or by the total removal of a valve itself.

Waste-preventing siphon cisterns are made in many

forms, but they depend principally for their action upon the mechanical displacement of a volume of water into the outlet limb of the siphons, or upon a pneumatic action. The pneumatic class possesses the merit of dispensing with rods and chains, and permits of their contents being discharged by the simple pressing of a button or of a small piston, etc.

Fig. 103 shows a displacer type of siphon waste-preventer, and its action is as follows: When the lever is pulled down the piston moves up the cylinder, displaces the water above it over the top of the siphon bend, and charges the vertical limb, when siphonage is established. It will be observed that the outlet limb of

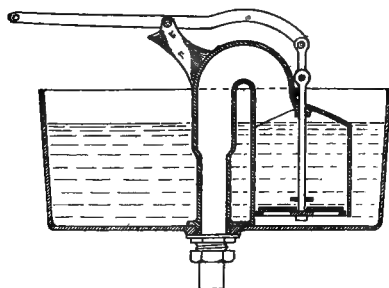


FIG. 103.—Waste-preventer (Doultons' "Speedwell"). Overflow and ball-cock omitted.

the siphon is reduced in diameter, instead of being made with a uniform bore; some form of contraction or enlargement should always be introduced into such siphons, as it has the effect of momentarily retarding the outflow of water at the commencement of the flush, enabling the siphon to be better charged, and of

making it more reliable in action. Because the rod of the piston in Fig. 103 passes through the top of the dome, no special air-hole is essential to break siphonage at the end of a discharge, as air will enter the siphon at the side of the rod, which is loose fitting where it passes through the dome.

A waste-preventer with pneumatic action is illustrated in Fig. 104. As the cistern fills, air is confined at the top of the chamber C. At the bottom of the siphon a disc valve V is provided, which opens on a hinge during the discharge from the cistern, but falls back upon its seating afterwards. A small pipe is joined to chamber C, and the other end of the pipe is connected with the small bellows B. When the cistern is filled to the water-line, siphonage is

established by pushing the knob K inwards in order to further compress the confined air in chamber C. The effect of this further compression is to dislodge sufficient water over the outlet limb of the siphon and to bring about the discharge.

Flushing cisterns are made in cast-iron, wood with metal linings, and in pottery ware. Iron flushing cisterns, unless protected with a glass enamel, or other suitable coating, are rapidly corroded with many soft waters, and the closets are also discoloured with rust. Lead-lined or copper-lined cisterns are more satisfactory for soft waters, the latter being the more durable of the two. Lead, however, has the advantage of being a little cheaper than copper. Pottery cisterns present a clean appearance, and are durable; they are more costly, however, than some of the other forms, and their use is limited in consequence. To prevent flushing cisterns being damaged by frost they should have sloping sides.

Lavatories.—The chief point of construction which requires consideration in connection with modern

lavatories is the arrangement of their overflows. Defects which were common in the earlier types of lavatories, such as small waste outlets, and soap dishes which discharge into overflows, or into traps beneath, are mostly absent in modern lavatories. These, like other sanitary fixtures, should be free from wood enclosures, and be constructed so as not to accumulate filth. Porcelain and enamelled fireclay are chiefly used in this country in the manufacture of lavatories, the latter material being used where specially strong and durable fittings are required.

A good shape of lavatory is the oblong form with straight

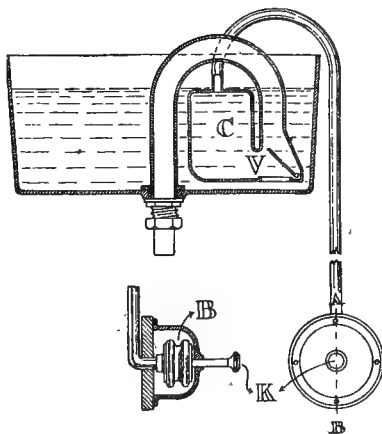


FIG. 104.—Adams' pneumatic action waste preventer. Ball-cock and overflow omitted.

front and circular back, the latter having a suitable recess in which the waste outlet may be located. All lavatories, whether in cheap or in expensive forms, should be provided with skirtings, to prevent water overflowing and trickling down behind them.

The tip-up form of lavatory, once largely used, is now superseded by simpler forms which are more readily cleansed. Tip-up basins possess an advantage in having a quick discharge, but their drawbacks, such as the fouling of the receivers, the disagreeable odours emitted by them when not regularly cleansed, and the wear and tear upon the trunnions, overshadow any merit they possess.

A weakness which is common to many present-day lavatories is in the form and size of the overflow. Overflows should be constructed in a manner which will admit of their being easily cleansed, be open to view, and be of a good size. Hidden overflows are liable to get their surfaces covered with slimy matter, which dries and emits that stuffy smell which is peculiar to apartments in which defective sanitary fixtures are placed; they also form suitable places in which disease germs may rapidly multiply.

In hospitals, schools, and other public institutions, it is of special importance that sanitary fixtures have no hidden parts which may be the means for the dissemination of disease.

In Fig. 105 two good forms of overflows are shown. That at A is formed within the basin, and made open as shown; it is readily accessible, and is easily cleansed by pushing a brush through it. The opening above the weir of the overflow may be covered by a thin metallic hinged flap if desired. At B, Fig. 105, an exposed standing waste is shown, which serves the purposes of overflow as well. This standing waste consists of a short metallic tube which admits of easy removal for cleansing. Porcelain tubes are also used for wastes, and present a clean appearance, but they possess the drawback of being easily broken.

Concealed standing wastes should not be used, even if they are made in a manner to admit of easy removal, for hidden surfaces, no matter how accessible, are not cleansed so regularly as those which are exposed to view.

C and D, Fig. 106, give two defective forms of overflows; neither admits of easy cleansing, but owing to its shortness the one at C is the better of the two.

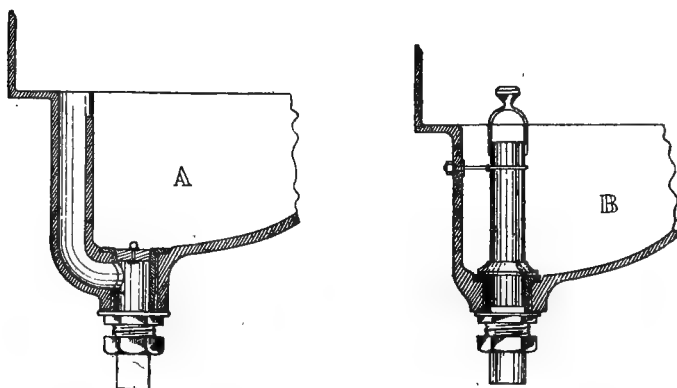


FIG. 105.—Good forms of overflows.

In public buildings, lavatories and similar fixtures are often fitted with combination hot and cold water valves, but many of these appliances are more trouble than they are

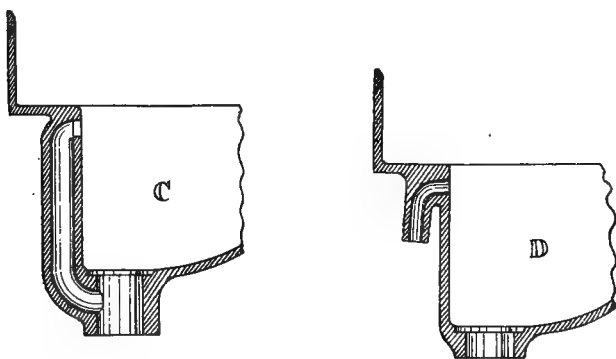


FIG. 106.—Defective forms of overflows.

worth. Combination cocks are frequently erratic in action and troublesome to repair. Independent hot and cold water cocks are, as a rule, the best fittings for lavatories and similar appliances, as they are cheaper, more durable, more easily

repaired, and the temperature and volume of the outflowing water are easily adjusted.

When lavatories are fixed with standing wastes, care should be taken to leave them in good working order. Occasionally it will be found that standing wastes when delivered from the works stick a little, and although the defect is easy to remedy, trouble has frequently resulted through neglecting it.

When loose plugs are used for lavatories, they should be made of a material which is incapable of chipping the glaze. Loose plugs and chains give very little trouble under ordinary circumstances, and they are simple and cheap.

Brass rods occasionally take the place of chains, to give a smarter appearance and to make a stronger fixing, but if the guides are fairly close fitting, the rods are liable to stick unless some lubricant is occasionally applied. On the other hand, if the plugs drop freely upon their seatings, there is a possibility of partially unsealing the traps, due to the sudden compression of the air at their inlets. This, however, applies more especially, to baths with tell-tale overflows than to lavatories, as the overflows of the latter would afford relief for the air.

For supporting lavatories, painted cast-iron or porcelain enamelled brackets and frames are very serviceable, and present surfaces which will only collect the minimum of dust. Where more ornamental fixings are required, various designs of friezes and standards may be used.

Ranges of Lavatories for offices, schools, hotels, works, and for other buildings, may readily be formed with separate lavatories, or with those having overlapping joints as in Fig. 107. In the range given, each lavatory is provided with a different but good form of overflow.

A more elaborate range of lavatories by Doultons is shown in Fig. 108.

Baths.—Some of the features that are necessary to produce a good type of bath are similar to those in an up-to-date lavatory. Baths vary in size and shape, are made of different materials, have several grades of finish, and differ in the kind and arrangement of their fittings.

The principal materials from which baths are made are cast iron and fireclay; each material has its special merits according to the class of building for which a bath is required.

The degree of perfection attained in the manufacture of cast-iron baths has done much to bring these fittings into general use, and they are produced in both cheap and expensive forms, suitable for either a cottage or mansion.

For most buildings, cast-iron baths with roll edges are the most satisfactory types. Iron is quickly heated when in contact with hot water, and the rolled edges dispense with the use of wood casings.

To protect iron baths from rust, and to give them a

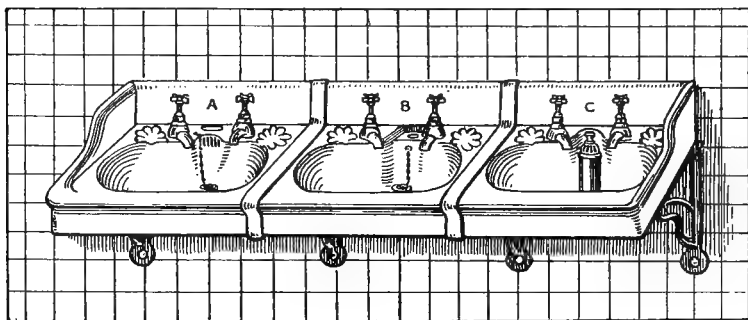


FIG. 107.—Range of lavatories with overlapping joints, by Twyford's Ltd.

smooth and satisfactory finish, their inner surfaces are enamelled, whilst their outer surfaces are more generally painted.

Metallic, vitreous, and porcelain enamels are used, and the grade of a bath is regulated by the kind of enamel used.

Metallic enamel is only the application of paint, which is fixed at a moderately high temperature, the number of coats regulating the finish desired.

Vitreous and porcelain enamels produce a smooth, glassy surface, which resembles that of glazed earthenware.

Glazed fireclay baths are very durable, and their surfaces are easily cleansed; these baths are specially suited

for public and other institutions, where they are often in demand, and where substantial fixtures are essential.

For private houses, however, fireclay baths when only occasionally used are not suitable; they are too heavy and cumbersome, absorb too much heat from the water, take a long time to heat through, and unless filled for a time before

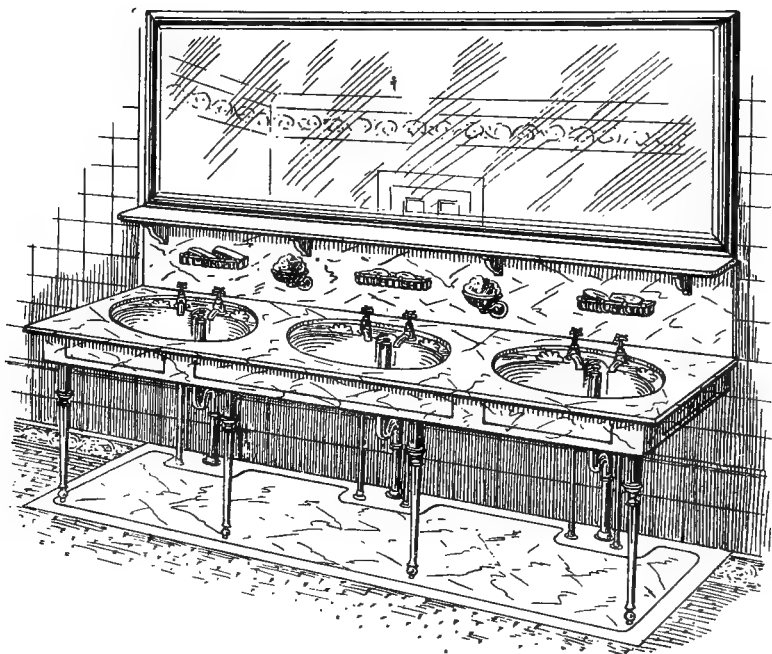


FIG. 108.—Lavatory range by Doultons Ltd.

they are actually required, their surfaces strike cold to the bather, especially in winter time.

Other materials, such as copper, tinned steel, and enamelled sheet iron, are used to a limited extent in the manufacture of baths, and these materials have the advantage of lightness and are suitable for special purposes.

For portable baths in hospitals and in other establishments, copper is a very satisfactory material, as it is a

good conductor of heat, and readily acquires a temperature which only differs a little from that of the water inside. On account of the expense of copper the cheaper materials named are frequently used where cost is the chief consideration. Portable baths for hospitals are frequently fixed on rubber-tired wheels, provision being made in the corridors for either filling them with water or for effecting their discharge.

Overflows and waste outlets of baths should be of simple

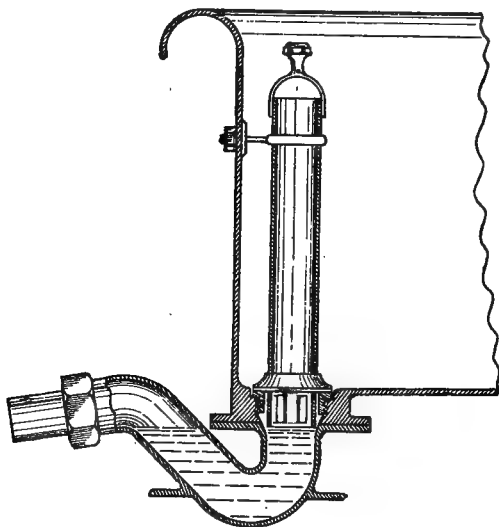


FIG. 109.—Standing overflow and waste outlet.

construction, and the traps should be fixed immediately beneath the outlets.

Fig. 109 shows a good form of standing waste and overflow, and the correct position for the trap, which may be either of brass, or of cast iron and glass enamelled inside. When standing wastes are used, recesses are necessary in the ends of the baths so that the wastes may be placed out of the way of the bather's feet.

A form of waste which is often used for expensive baths is given in Fig. 110. These wastes present a nice appear-

ance when well polished or silver plated, but they are very objectionable from a sanitary standpoint, as they contain surfaces upon which filth is liable to gather and to remain unobserved.

It will be noticed from the construction of the waste, that water will rise in the annular space between the tubes when a bath is filled, and in consequence soapy matter is liable to be deposited upon the surfaces when the bath is in use.

Some Water Companies, however, do not allow overflows of baths to discharge into their waste pipes, but require

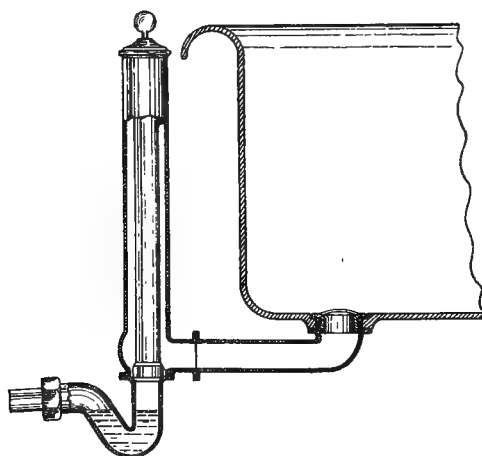


FIG. 110.—Defective form of standing overflow.

them to be arranged as in Fig. 111. To the outlet a length of pipe is attached, and the other end of the pipe terminates in the open air, so as to serve the purpose of a warning pipe. This form of overflow was introduced with a view to minimise waste of water, but its value for that purpose is very

questionable. It is, however, a very defective form of overflow, as it does not permit of being cleansed, and it allows cold air to flow into the bathroom, along with any fine particles of matter which have been deposited on the surfaces of the pipe.

For hospitals and other places where it is desirable to have special facilities for cleansing the floors and walls of bathrooms, baths may be obtained which revolve round their waste outlets. This arrangement is specially useful where space is limited, as a bath when in use may be turned from the wall of an apartment so as to allow an attendant to get on either side.

Sinks.—The uses of sinks are varied, and different materials are used in their formation. Well glazed fireclay sinks are specially suited for small houses, and they may be obtained in inexpensive forms. For mansions, hotels, restaurants, and public institutions, glazed fireclay is the most suitable material for sinks for general purposes, and for vegetable sinks. A softer material, however, is often necessary for sinks which are used for washing glass and china ware, in order to minimise the risk of chipping these goods. Where a moderate amount of care is exercised, and where sinks are fairly deep and wood drainers are used, fireclay sinks are often suitable for cleansing china ware, but for large buildings it is usually desirable to provide special sinks for this purpose. Hard wood, such as teak, and also softer woods (when the latter are protected with soft metal linings, make good sinks for washing crockery ware. Metal-lined sinks are superior to those made entirely of wood, for after a time decay sets in, and the wood becomes saturated with greasy water, and during the partial drying of this material offensive odours are also emitted.

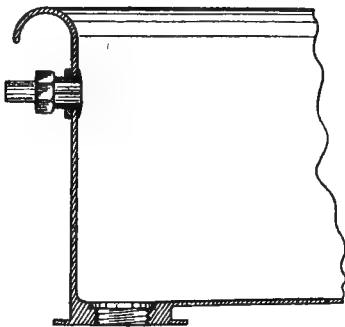


FIG. 111.—Tell-tale overflow.

Where sinks are used that are lined with either block tin or lead, their sides should be tapered so as to allow the linings to slide a little inside the wood casings when the metal expands and contracts. Sinks with vertical sides rigidly hold soft metal linings, and cause the latter to buckle and crack when alternately heated and cooled.

Fig. 112 shows a wood sink, and a suitable method of lining it with either tin or lead. The metal, it will be observed, is not turned over and nailed down on the top edges of the sink, but is trimmed off a little below the top edge, and held by means of an oak capping piece which covers the free edge of the lead. When a wood sink is treated in this

manner the metal linings will move a little and as a consequence will have a much longer life.

Butler's Sinks are frequently made of tinned copper, and are oval in shape; or larger sinks may be of wood and be lined with tin.

Drainers for sinks when made of teak are durable, but when soft woods are used they should be covered with either block tin or lead, the former metal, of course, being the better of the two.

Sheet lead or tin is readily worked into the grooves of a drainer after it is first heated to about 200° F. either through the agency of boiling water or by other means. The metal should be rubbed into the grooves, as any attempt to drive it in will result in the metal straightening out from one, as it is driven in another groove.

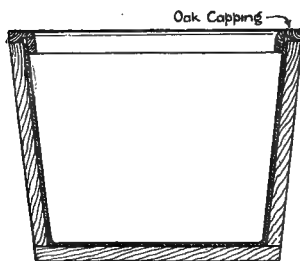


FIG. 112.—Method of securing metal lining along top edge.

With regard to overflows, these should not be formed in sinks from which greasy matter is discharged, unless damage is likely to be caused should they overflow. In many sinks overflows are objectionable and are not required.

Cast-iron sinks, with plain or enamelled interiors, are also made, but the former have a dirty appearance, and the latter although cheaper than those of fireclay are less durable.

Wash-Tubs.—These fittings require very little commenting upon, as they resemble sinks excepting that they are deeper and have their fronts formed with a good slope. The most suitable material for wash-tubs is enamelled fireclay. Overflows to these fittings are unnecessary, and only a simple form of waste outlet is required. On account of the weight of fireclay tubs pedestals of the same material make the best forms of supports.

Slop Sinks.—In construction, slop sinks are similar to water-closets, and their outlets should be readily accessible, and permit of a simple and effective joint being made with the branch waste pipes. A good form of slop sink is given

in Fig. 113. In the basin, either a brass or galvanised iron hinged grate is provided, upon which a pail can be placed. Hot and cold draw-off taps are often fixed immediately above the sink to enable water to be obtained for cleansing purposes. An overhead flushing cistern is essential for these sinks, so as to cleanse them after discharging slops into them.

For hospital use special forms of slop sinks are necessary, as provision must be made for flushing out bed-pans, etc.

Urinals.—During the last few years great strides have been made in the design and construction of urinals, and many defects which were common in the earlier types are mostly eliminated in the best modern fixtures.

The urinal is the most difficult of sanitary fixtures to keep in a satisfactory state of cleanliness, and more especially so when cumbersome and useless pieces of pottery are utilised in their construction.

All urinals require a liberal supply of clean flushing water, as urea from the urine is readily decomposed, and gives off the well-known ammoniacal odours which are common in badly flushed and poorly constructed urinals.

In private houses a w.c. serves the purpose of a urinal, but for works, clubs, hotels, schools, and many other buildings, as well as for public thoroughfares, independent urinals are a necessity.

Urinals commonly take the form of lipped earthenware basins, of enamelled iron and fireclay troughs, and of slate and fireclay stalls. Well glazed and constructed fireclay stalls make the best types of urinals, but these are usually

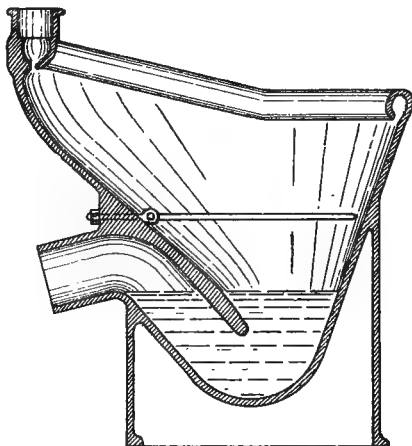


FIG. 113.—Slop hopper.

more costly than other forms, excepting those where marble enters into their construction.

From a general standpoint, trough urinals when arranged to stand nearly full of water make good forms provided that they are properly used and flushed, as the urine is diluted with a large volume of water. Trough urinals, however, are often subjected to improper use, and they soon become offensive

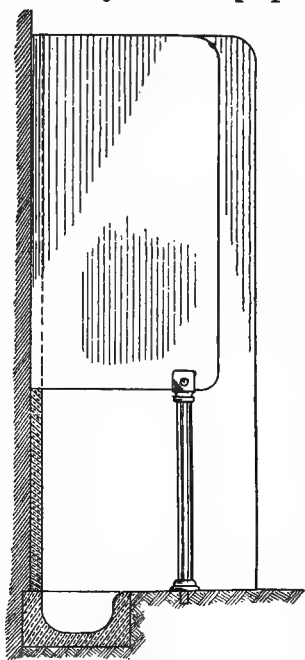


FIG. 114.—Form of slab urinal.

owing to portions of their surfaces getting wetted with urine and which are never properly flushed.

Stall urinals which are formed of slate slabs do not admit of the whole of their surfaces being cleansed, and therefore this type is not suitable for installing inside buildings or in confined situations. If, however, for economical considerations, slab urinals are adopted where they can be exposed to the external air, the division slabs should terminate about 18 inches clear of the channels in the floors, and be supported at the front by means of galvanised iron columns as shown in Fig. 114. The floor channels should be of glazed earthenware with an outlet at one end, or in the case of a long range the outlet may be better located near the centre.

Slab urinals, Fig. 114, may either be of slate or glazed fireclay, the former being the cheaper of the two, but the latter can be the more readily cleansed.

The chief points to consider when selecting semi-circular or radial back urinals are:—

1. That they are constructed in well-glazed fireclay or similar ware.
2. That they are made in as few pieces as practicable, to limit the number of joints.

3. That they contain the minimum length of channel.
4. That all surfaces which are liable to be wetted with urine are effectively flushed.
5. That the minimum number of traps be used.

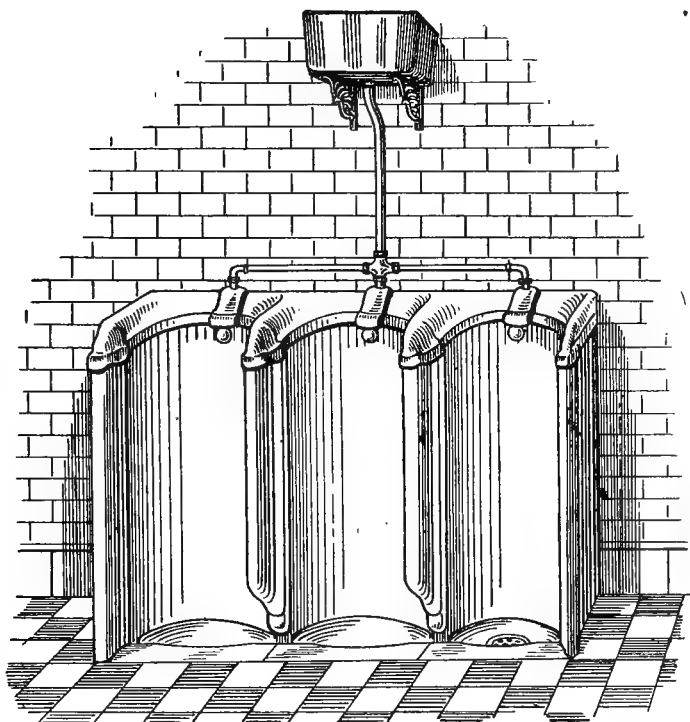


FIG. 115.—Twyford's urinal range in glazed fireclay.

6. That the joints are well formed, and arranged, as far as it is practicable, so as not to come in contact with the urine.
 7. That no part of a channel be difficult to cleanse or be partially obscured from view.
 8. That suitable flushing apparatus, together with a liberal supply of water, be provided.
- Single stall urinals, provided that they are of good

design, present very little difficulty, as they can be formed in one piece of fireclay; when, however, ranges of urinals are formed, joints become imperative, and the effective discharge of the urine from the stalls becomes a more difficult matter.

Joints in the channels of range urinals are frequently a source of weakness, and in order to overcome this defect each stall is occasionally provided with a separate outlet and trap. Traps, however, when numerous are objectionable, owing to the volume of urine they hold, and the connections between the channels and traps are frequently of defective design.

In order that one trap may suffice for one or more ranges of urinals, main channels are sometimes arranged along the front of the stalls, and covered with movable iron or brass gratings; a small branch or subsidiary channel from each stall joins with the main channels, and the whole of the channels are made to fall to a common outlet where a trap is provided. The chief drawback of this arrangement is in the length of channel required, and unless the whole of the grates and channels are frequently cleansed by an attendant they are liable to get in a very unsatisfactory state.

A good form of urinal is shown by Fig. 115, where an open, continuous channel is made in the urinal itself, and where the facings of the divisions terminate clear of the channel.

Inlets to urinal traps should be covered with a domical grating to avoid, as far as practicable, the accumulations of burnt matches and other matters from choking up the grating and causing the floor of an apartment to be flooded.

CHAPTER VII

SOIL AND WASTE PIPES

Soil Pipes.—Although from a legal point there sometimes appears a little difficulty in interpreting the term “soil pipe,” the ordinary individual generally understands it to mean a pipe or channel above the level of the ground, communicating with one or more water-closets and a drain; the purpose of a soil pipe being to convey discharges from w.c.’s to a drain.

Materials.—The materials of which soil pipes are made are lead, cast iron, and occasionally copper. *Solid drawn lead* pipes have many advantages as soil pipes; they are very durable when properly fixed, have smooth surfaces which when properly flushed are easily cleansed; they can be securely jointed, can be fixed in long lengths; are easily bent to suit various situations, and contain the minimum number of joints.

Lead as a material for soil pipes also has drawbacks. One of the disadvantages of lead soil pipes is their higher initial cost when compared with iron pipes, although if the durability of the former, and their intrinsic value as old material, were taken into account, lead pipes would finally prove the cheaper to use. Another disadvantage is that lead soil pipes are liable to be bent and disfigured by expansion if exposed to the direct rays of the sun. This difficulty can be overcome by protecting them, when in exposed situation, with iron shields, which are made to represent square or rectangular iron pipes, but the extra cost involved would often be prohibitive.

To prevent lead pipes from being distorted by expansion, expansion joints are occasionally used, but the form of joint

generally adopted for these pipes is not reliable, and it is also troublesome to repair.

Iron Soil Pipes possess the advantages of being self-supporting, of being easily fixed, and of being cheaper than lead pipes at the outset. The surfaces of iron pipes, however, require some form of protective coating to preserve them from rusting.

Drawbacks of iron soil pipes are:., they are not so durable and smooth as those of lead, special bends and other fittings are often required, the interior surfaces of the pipes get rough owing to the decay of the protective coatings, and they contain comparatively a greater number of joints.

Copper Soil Pipes are too expensive for general work, but where their surfaces are tinned, and these pipes are properly jointed, they are suitable for high class work where lead pipes may prove unsatisfactory.

It is no unusual occurrence for the bottom length of an unprotected lead soil pipe to be damaged when in a position where it can be kicked, and occasionally a length of iron pipe is inserted at the bottom of a stack when lead pipes are likely to be subjected to improper usage.

Thickness of Soil Pipes.—The walls of lead soil pipes should not be thinner than 7-lb. lead, and for good work a thickness equal to that of 8-lb. lead should be used. The thickness of iron soil pipes should not be less than $\frac{1}{4}$ inch, to enable sockets of sufficient strength to be formed. A 6 feet length of 4 in. \times $\frac{1}{4}$ in. cast-iron soil pipe should weigh not less than 60 lb.

In Great Britain, it is the usual custom where practicable to fix soil pipes on the external face of outside walls. Although this practice has much to commend it under ordinary circumstances, such positions are not conducive to the best results so far as the ventilation of drains is concerned. Soil pipes when fixed inside buildings are protected from the inclement weather of winter, and they may be made fairly accessible. On account of the protection afforded to inside pipes in cold weather ventilation is active, whilst with pipes in external positions, ventilation would be practically stagnant. Where soil pipes, however, are fixed inside

buildings there should be no doubt about the soundness of the work or of the quality of the materials used, and every precaution should be taken to make them satisfactory in every respect.

Soil pipes when fixed on the outer surfaces of walls possess the advantages of being exposed to view, and in the case of a defect less harm is likely to be done than with a defective inside pipe.

Climatic conditions also regulate the positions of soil and waste pipes. In countries where it is extremely cold in winter, with the thermometer sometimes recording zero and below, there is the possibility of outside pipes getting blocked with ice.

Arrangement of Soil Pipes and their branches. The chief points to consider when arranging soil pipes are: that their branches can be suitably placed, have good pitches where practicable, and that reliable connections can be made; that antisiphonage pipes do not cross the soil pipes unless absolutely necessary, that as few joints as possible be buried in walls, and that all branches which join a soil pipe curve in the direction of the flow.

Fig. 116 shows how the crossing of pipes may be avoided where the water-closets are located immediately in front of windows, by fixing the main soil and principal antisiphonage pipes on different sides of the windows. At A, Fig. 116, all the pipes are supposed to be of lead, whilst the main pipes and junctions in B are of iron, with lead branches passing through the walls to the fittings.

When iron pipes are used rust pockets should be provided on the antisiphonage pipes, with means of access to enable accumulations of rust to be readily removed.

It often occurs that a straight branch between a soil pipe and w.c. requires to be fixed as Fig. 117, and although this form of branch presents no special difficulty when lead soil pipes are adopted, the use of iron pipes and of an ordinary short junction causes a joint to come in the wall. Where the work is properly carried out, and the soil pipes are periodically tested, joints in walls are not so objectionable, but for general work it is better to have all joints where they can be

readily seen and easy of access. In Fig. 117 a special iron junction with long branch is shown, together with an antisiphonage pipe connection which is indicated a little on one side of the branch.

Soil pipes should always discharge directly into drains,

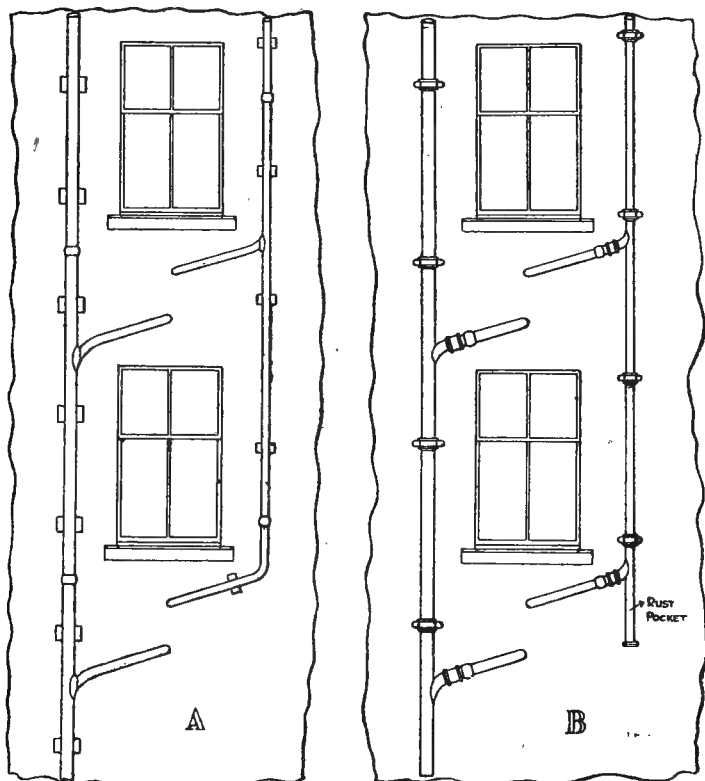


FIG. 116.—Lead and iron soil pipes.

that they may also act as ventilating pipes for the drainage system. The upper ends of soil pipes should terminate so as to be well removed from dormers, chimneys, and other places that afford direct communication with the interiors of buildings.

When a soil pipe comes too close to a dormer it should be carried up the roof, and terminate at a suitable elevation

above the dormer. If a soil pipe should terminate near the top of a chimney, drain air may frequently pass down the chimney under certain atmospheric conditions, and especially so when no fire is burning in the grate. It is therefore obvious that unless soil pipes terminate in suitable positions that the value of sound joints, good materials, and special forms of connections are very materially nullified.

In large buildings, where ranges of closets are fixed immediately beneath one another, and where long branches are required, great care is necessary in the arrangement of the pipes. To fix single closets over one another is com-

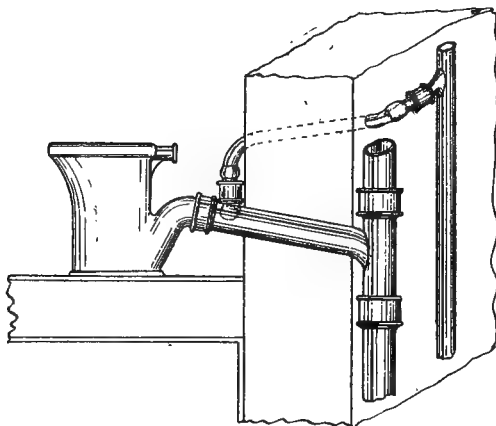


FIG. 117.—Special iron junction.

paratively simple work, but when ranges of closets are required on various floors the soil-pipe work is of a more complex character, and both thought and skill are essential to plan and properly execute the work.

Plan and section Fig. 118 show the arrangement of the soil-pipe work on one of the floors of a large building, the fittings being omitted in order to make the connections clear. The main soil pipe and antisiphonage pipe are fixed on the outside face of a wall, whilst the long branch B which intercepts the connections from the closets is situated beneath the floor. The pitch available for branch B is limited by the depth of the floor joints, and as the distance

between the floor and top of the long branch is very limited, the short connections from the closets should take the form of

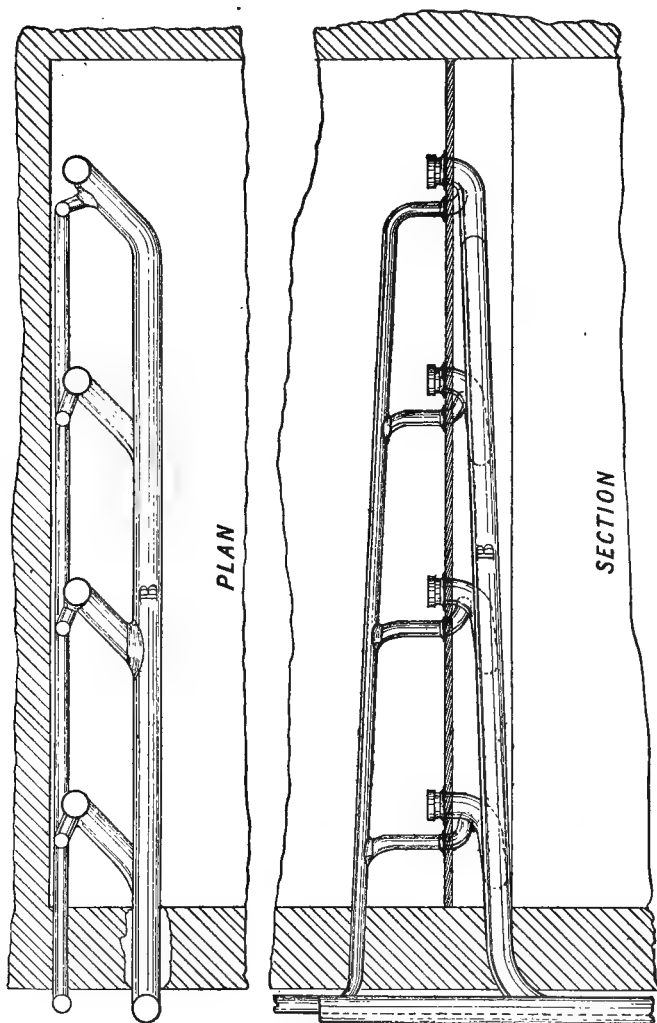


FIG. 118.—Lead soil-pipe work for four w.c.'s.

bends, and be joined at the side of the long branch B, as shown on plan. Assuming that the long branch B, Fig. 118, is fixed close to the wall, and that closets with back outlets are

used, the short connections would be nearly straight, and so enter branch B at nearly right angles. Right-angled connections would of course cause waste matter at each discharge to flow in both directions in the horizontal branch, so that solid matter would often lodge on the higher side, until it was removed by a discharge from another fitting. The arrangement in Fig. 118 allows discharges to enter the main channel in a manner that all solid matter may be removed at each flush. The branch antisiphonage pipes are all shown connecting with the bends, to which the closets are also directly joined, as this method allows reliable joints to be made.

To facilitate the fixing of the pipes, and to permit of the greater portion of the work being executed in the workshop, flange joints may be made in connection with the lead pipes as in Fig. 119, which shows enlarged detailed connections for one

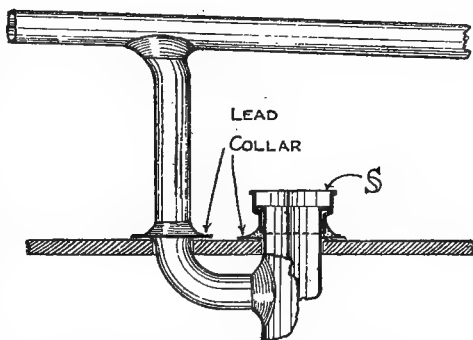


FIG. 119.—Enlarged detail in connection with Fig. 118.

w.c. Lead collars should, of course, be slipped over the ends of the pipes before the latter are flanged over on the floor. To prevent the distortion of the pipes through the opening of their ends, those to be expanded should first be heated with a lamp or by other means. If an ordinary brass socket S, Fig. 119, is used for a closet connection, it may require to be shortened a little, so that its lower edge will stand clear of the lead collar on the floor as shown. The brass sockets when treated in the manner described allow simple air-tight joints to be made, besides forming suitable fixings for the bends.

It will, of course, be understood that the floor joists in Fig. 118 are assumed to run in the right direction, thus allowing

the long branch to be fixed in the manner shown. If, however, the pipes cannot be located beneath a floor as in Fig. 118, either a raised platform would be necessary or closets with P traps

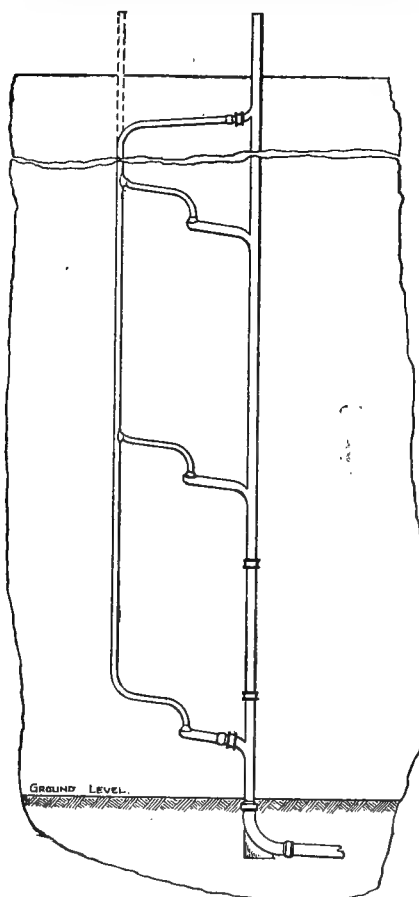


FIG. 120.—Connections of antisiphonage pipes with bends on the outside face of a wall.

would require to be used. Even assuming that the latter plan were adopted, a low platform may still be essential to give the necessary pitch if the branches were long.

Much time is saved in executing this class of work and it is much easier to carry out if full-sized working drawings are used. All the bends can then be formed to correct pitches, branch joints prepared, whilst a number of joints may be made before the pipes are placed in position.

Antisiphonage Pipes.

—Because traps are liable under certain conditions to have their contents siphoned out, antisiphonage pipes are provided to preserve the equilibrium of the air pressure on the inlet and outlet sides of traps.

Joints on these pipes should be carefully prepared to enable air to flow through them without unnecessary interruption. When a soil and antisiphonage pipe are fixed on a wall fairly close together, it is unimportant whether the antisiphonage pipe joins the soil pipe above the highest branch,

or whether it is continued and terminates as shown by dotted line in Fig. 120.

Instead of joining antisiphonage pipes with the soil pipe branches in the w.c. apartments, they are frequently connected to the bends on the outside face of a wall as in Fig. 120. This method of dealing with the antisiphonage pipes possesses the advantage of simplifying the fixing of these pipes, and it is very suitable where the w.c.'s are fixed immediately at the back of the wall, or where very short portions of the branches are left without direct ventilation.

The bye-laws of the London County Council limit the position of the antisiphonage pipe connection to not less than 3 inches and not more than 12 inches from the top of a trap, so that the arrangement in Fig. 120 would not often satisfy the bye-laws in question. Although the 12-inch limit may be sufficient to meet many cases, there are many others where this distance could with advantage be increased. For example, take a case like Fig. 121, where it would be positively absurd to join the anti-siphonage pipe with the branch soil pipe near the middle of the wall, as indicated by dotted lines, in order to satisfy the 12-inch limit, when a few more inches away would allow the joint to be made in a more rational place.

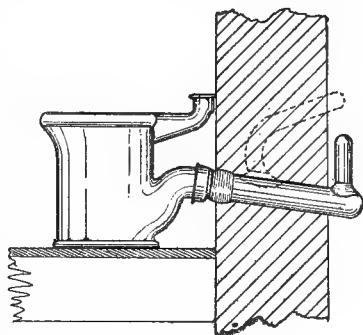


FIG. 121.—Lead branch and anti-siphonage pipe.

Sizes of Soil Pipes.—No formula is necessary to calculate the sizes of soil pipes, as these are entirely governed by practical considerations. The general size of a soil pipe is 4 inches diameter, not because a smaller size is inadequate to carry away the discharges from a number of w.c.'s, but because this size makes a fairly effective outlet ventilator for a drainage system, and because it may be kept in a fair state as regards cleanliness.

Soil pipes of $3\frac{1}{2}$ inches diameter are better than those

of a larger size so far as the cleanliness of their inner surfaces is concerned, but for a principal outlet ventilator a $3\frac{1}{2}$ -inch pipe is rather small, and especially so when there is a number of bends in the stack. When a stack of soil pipes is not required to act as a drain ventilator, smaller diameters may be used; but special attention requires to be devoted to the sizes of the antisiphonage pipes, for the better a stack of pipes is scoured with flushing water, the more readily will traps lose their seals, unless adequate means be provided to counteract it.

The question is sometimes asked, how many w.c.'s may be discharged into a stack of 4-inch pipes without causing overflow at any of the lower fittings? The exact number would be difficult to state, as it depends upon a variety of conditions, such as the possible number of w.c.'s likely to be flushed at the same time, the type of closet used, the amount of obstruction offered to a discharge by bends, etc., in the pipes, and also upon the arrangement of the pipes. Thus it will be clear that only a hypothetical solution can be arrived at. The time to flush a wash-down closet through a $1\frac{1}{2}$ -inch discharge pipe with $2\frac{1}{2}$ gallons of water may be taken as 5 seconds, and if the area of the $1\frac{1}{2}$ -inch pipe and that of the 4-inch soil pipe are compared, the latter will be found to be rather more than 7 times that of the former; thus

$$\frac{4^2}{1\frac{1}{2}^2} = \frac{4}{1} \times \frac{4}{1} \times \frac{2}{3} \times \frac{2}{3} = 7\frac{1}{9}. \quad \text{If it is assumed for the sake of sim-}$$

plicity that liquid matter is discharged into and through a stack of 4-inch soil pipe with a uniform velocity, then seven w.c.'s could be flushed simultaneously into one stack without quite filling it. But as the velocity of discharge through a soil pipe varies according to the height through which the matter falls, at least one more w.c. could be safely added to the number obtained. We have now $7+1=8$ w.c.'s which may be discharged into a 4-inch soil pipe at the same instant. It may further be safely assumed that not more than one-fourth of the w.c.'s on a stack of pipes is likely to come into use at the same time, especially when the interval of flushing is of such a limited duration. Reasoning on these lines, we now have $8 \times 4 = 32$ wash-down w.c.'s as a number which

may safely be joined to one stack of 4-inch pipes, so far as the discharging capacity of the latter is concerned.

As it is not desirable to use soil pipes larger than 4 inches diameter, an additional stack should be provided in lieu of one of an increased diameter where there are too many closets for a single stack of pipes.

Although in many cases antisiphonage pipes are made compulsory where more than one w.c. is discharged into a soil pipe, the value of the former pipes has often been questioned, and by some considered unnecessary. There is not the slightest doubt that, like many other things, anti-siphonage pipes have been occasionally overdone, for when the spirit of reform has taken hold of a community, whether in sanitary or in other matters, it is generally the practice to rush from one extreme to the other. Before the ventilation of soil and waste pipes received the attention it does at present, these pipes were generally unventilated; the result of this was, that when two or more w.c.'s were joined to a stack of pipes, the discharge from either one displaced a certain volume of air from the soil pipe, and diminished its internal air pressure. As no air inlets were provided to enable the external and internal pressures to be immediately equalised, the water seal which offered the least resistance was broken, and the requisite amount of air was admitted from that source.

But where two or three wash-down w.c.'s are fixed over one another on a stack of 4-inch pipes, which are carried up full bore to the roof for ventilation, the removal of the water by siphonage from any of the traps may not readily occur by a single flush, owing to the freedom with which air may enter and make good that displaced by the falling body of water. It is often from such a simple case as this that the opponents of antisiphonage pipes draw their conclusions.

Numerous experiments have been conducted from time to time to show how traps may have their contents removed by siphonage and by other means, but many of these experiments possess little real value, as they are often conducted under very limited and unreal conditions. Whether the water seals of traps will be broken by siphonage or not

will depend principally to what extent the outlet pipes are charged, upon the velocity of discharge, and upon the provision for ventilation.

Taking the case of a 4-inch stack of soil pipes which receive the discharges from say four w.c.'s, if the stack is continued full bore for ventilation, is free from bends, and the wash-down type of w.c. is used, the flushing of the topmost w.c. may not affect the water seals of those below even though antisiphonage pipes were not provided. If, however, a stack is high, and contains a number of bends, and two or more w.c.'s are flushed at the same time, it may be possible for the combined discharges to remove the seals from the lower fixtures.

Where a stack of soil pipes is not provided with antisiphonage pipes, there is often a risk of the lower traps losing their seals by the rapid discharge of a pailful of slops through one of the higher fittings. The top w.c., of course, on a stack of pipes does not require an antisiphonage pipe, but where the main antisiphonage pipe is joined with a soil pipe, the junction as a rule is made above the highest fitting.

Sizes of Antisiphonage Pipes.—The size of these pipes should be governed by the general arrangement of the soil pipes, and by the type and number of closets that are joined to one stack. Wash-down w.c.'s admit of the smallest sizes of antisiphonage pipes being used, as the discharge in leaving these closets is more prolonged than with either the valve or siphonic types.

The object to be attained in all cases is to have antisiphonage pipes of a size that will allow the necessary amount of air to pass through them, and at the same time to prevent undue air tension in any branch when a volume of water is being discharged. There is no simple formula known to the writer for determining the size of antisiphonage pipes; judgment, and a good knowledge of the law of falling bodies and of the flow of fluids through pipes, appear to be the most reliable guides.

When water is discharged from a w.c. into a soil pipe it is a common error to assume that it falls through the

latter in the form of a solid plug. It will, however, be found that a vertical soil pipe is only partially filled, and that a discharge, with the exception of excrement and paper, etc., chiefly follows the surface of the pipe.

If it is assumed that 3 gallons of water are discharged into a stack of soil pipes of indefinite height in four seconds, then according to the law of falling bodies the first particle of water, if uninterrupted in its passage, would have fallen through a vertical distance of 256 feet by the time the last particle was ready to fall. In other words, the 3 gallons of water would be spread over a length of 256 feet of pipe. As resistances are encountered by falling water in a soil pipe, the height, of course, would be much less than that given.

The length of 4-inch pipe which will hold 3 gallons of water is about 5 ft. 6 in. Of course the height of a soil pipe is limited, but the example simply serves to show the small area often occupied by water when the latter is falling through a pipe.

Fig. 122 represents four w.c.'s which are fixed above one another and discharge into one stack of pipes; the antisiphonage pipes are all shown to be 2 inches diameter, and this size would be ample where wash-down w.c.'s were used. If siphonic w.c.'s were fixed, the main antisiphonage pipe might be increased to $2\frac{1}{2}$ inches diameter for the upper half of its length. It is seldom desirable to use branches for antisiphonage pipes smaller than 2 inches diameter, on account of the smaller sizes being more easily choked.

The effect of the arrangement of soil pipes on the sizes of antisiphonage pipes is illustrated in Figs. 123 and 124. If the pipes are arranged as Fig. 123, and a volume of water is discharged simultaneously from two or more of the upper fittings, the air to replace that extracted from a lower

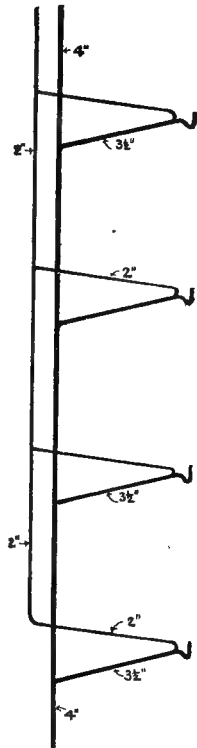


FIG. 122.—Sizes of soil and of ventilating pipes.

horizontal soil pipe branch would require to enter through the small branch antisiphonage pipes. This arrangement may necessitate the lower horizontal antisiphonage pipe branches being about 3 inches diameter.

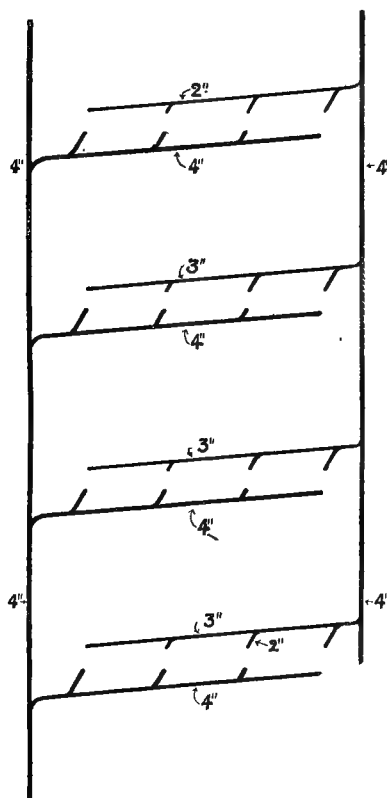


FIG. 123.—Diagram illustrating the effect the general arrangement has upon sizes of ventilating pipes.

In Fig. 124 the horizontal soil pipe branches are shown continued and joined with the main antisiphonage pipe, and as air tension would be directly relieved in any of the principal branches by this means, the horizontal antisiphonage pipes may be of smaller bore than those in Fig. 123; neither would it be imperative to ventilate each w.c. branch separately, but they may be treated as shown in the upper portion of Fig. 124, provided they are only short.

For very high stacks of soil pipes which have a large number of closets connected with them, it may be desirable in a few very special cases to make the principal ventilating pipe a little larger than 4 inches diameter; this, however, will greatly depend upon the arrangement of the pipes.

It will be observed in Fig. 124 that instead of continuing the horizontal soil pipe branches, and joining them directly with the main antisiphonage pipe, that their junctions have been effected by separate branches. This arrangement prevents the deposition of excrement at the higher end of the long branches.

Unsealing of Traps.—There are various ways by which a trap may lose or partially lose its water seal, such as by siphonage, by momentum, by capillary attraction, by evaporation, by waving out, and by the water being blown out through the compression of air.

As already explained, siphonage is produced when the water surface at the outlet of a trap is subjected to a less pressure than that on its inlet side, and to prevent siphonage, all that is necessary is to maintain equilibrium of the air pressure on the inlet and outlet sides of a trap.

Unsealing by *momentum* has reference to where a volume of water in flowing through a trap encounters insufficient resistance to prevent enough water remaining in the trap at the end of the discharge. Traps in connection with slop sinks, or other fixtures where water is discharged rapidly through them, are liable to be unsealed by momentum, unless their outlets are flattened so as to retard a little the out-flowing water. Traps for baths, ordinary sinks, and

for similar fixtures, are not liable to be unsealed by momentum; neither are the traps of ordinary lavatories, or those of wash-down w.c.'s when the latter are flushed in the usual manner. When unsealing by momentum requires to be taken into account, the best form of trap to use is the

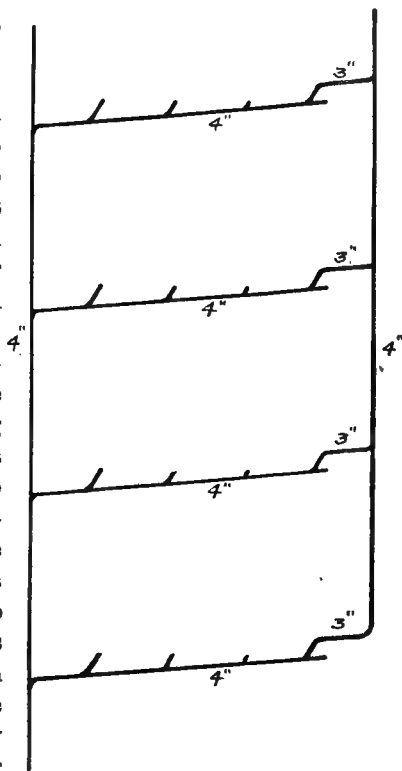


FIG. 124.—Diagram illustrating the effect the general arrangement has upon sizes of ventilating pipes.

anti-D type. An antisiphonage pipe is not a cure for loss of seal by momentum, and the remedy lies in the provision of a suitable trap.

Loss of seal by *capillary attraction*. When traps are not self-cleansing, fibrous matter may hang over their outlets and remove the water from them by capillarity. The liquid rises through the interstices of the matter, and the smaller the interstices the greater the height to which the liquid will rise. As the seals of traps are comparatively small they are readily broken by capillary attraction. To remedy and to avoid this evil all that is required is a self-cleansing form of trap.

Unsealing by *evaporation*. In this country the water seal of a trap is not readily removed by evaporation, and only where fixtures are out of use for a comparatively long period, or when located in heated apartments, is it likely for a trap to lose its seal by this agency. The atmosphere, except when in a saturated state, is constantly taking up moisture from any available source, so that unless traps are replenished periodically with water their seals will be eventually broken. For houses which are closed for long periods during hot weather the water seals of traps may be maintained for a much longer time by putting oil on their water surfaces. A syringe with a bent tube could be used for forcing oil to the outlet side of a trap, but very few people will take this trouble.

Unsealing by *waving out*. Where the wind can blow directly across the end of a pipe, or down it, the air inside in the first case is under tension, whilst in the latter it is subject to more or less compression according to the force of the wind. The partial unsealing of the traps of w.c.'s is very common where the upper ends of soil pipes are left plain and unprotected, and where no fresh air inlet is provided for the drainage system, or where the inlet is temporarily closed. The sudden compression of the air in a soil pipe by a gust of wind depresses the water level on the outlet side of a trap, with the result that when the force is spent a portion of the water washes over the outlet in regaining its normal level by the motion imparted

to it. A similar effect may be produced when the air in a soil pipe is rarefied by a strong current of wind passing over its open end.

Unsealing by the *blowing out* of water. The traps unsealed by this means are usually those which are situated at a low point, and where the air in a system of pipes is put in compression by a falling body of water. In the case of soil pipes which are connected directly with drains, and where the latter have fresh air inlets which are either choked or automatically closed by an outward rush of air, a discharge from a w.c. at a high level is often sufficient to compress the air in the drainage system for a brief interval; under such conditions relief is usually obtained by blowing out the water from one of the traps. The unsealing of traps in this manner can be prevented by making provision for a free flow of air through the drainage system, in either direction.

Waste Pipes.—The arrangement of waste pipes is to a great extent the same as for soil pipes, the chief difference being that waste pipes are generally disconnected from foul-water drains by means of traps, whilst soil pipes are connected directly with a system of drains. The waste pipes from slop sinks and urinals are, however, exceptions to the general rule, and are treated in the same manner as soil pipes.

In America and other countries where climatic conditions necessitate the soil and waste pipes being fixed inside buildings, in order to protect them from frost, separate soil and waste pipes are not generally used, but all the different sanitary fixtures which are located near each other discharge into a pipe common to the whole. Through British spectacles such an arrangement is often thought to be a retrograde one, but when reasoning to a logical conclusion it will be found sound in principle, when pipes and traps of suitable materials are used, when the workmanship is all that can be desired, and when special attention is paid to the ventilation of the different pipes.

Where it is essential to fix soil and waste pipes inside buildings, they are, under ordinary conditions, as well joined together at a high elevation as to be carried down separately into a basement and there connected with a

common drain, provided the essential conditions of good workmanship and suitable materials, etc., are fulfilled.

In Great Britain, where waste and soil pipes are fixed outside buildings, their separation in some cases is quite defensible, for where soil pipes are of lead it is imperative that hot waste water should not be discharged into them.

Bath and Lavatory Waste Pipes.—The lower portion of a stack of waste pipes is shown in Fig. 125, where a bath and lavatory are supposed to be fixed close together on each of two floors. The main waste pipe is supposed to be of cast iron, whilst the branch pipes are of copper, with brass fittings.

All the antisiphonage pipes of Fig. 125 are of lead, and are shown located inside the building; these pipes should be carried up and terminate at a high level, or be joined with the main waste above the highest branch.

For good buildings the smaller waste pipes should be of copper for the discharge of hot water, and especially when the branches are long. The first cost of copper waste pipes is rather high, but they can be relied upon and are durable. The branch wastes should not be too rigidly fixed, but so arranged that they may move in the direction of their length. Sufficient space for movement may often be obtained at one or more bends, but if it is necessary for a branch to be fairly straight between two fixed points, and of moderate length, an expansion joint may be provided near the trap as at A, Fig. 125.

In copper waste-pipe work a fair number of union connections is necessary, but in many cases a simple form of brazed socket joint can be adopted.

Sometimes antisiphonage pipes are also of copper, and these have a smart appearance when they are lacquered and kept bright. Antisiphonage pipes, however, are not subjected to the same strain as waste pipes, and lead pipes are satisfactory so far as durability is concerned, and also have the merit of being readily fixed.

Sizes of Waste Pipes for Baths and Lavatories.—The waste pipes for both baths and lavatories should be of a

reasonable size, so that these fixtures may be quickly emptied, and the discharge of water be of service for aiding in the cleansing of the drains. A waste pipe from a bath should

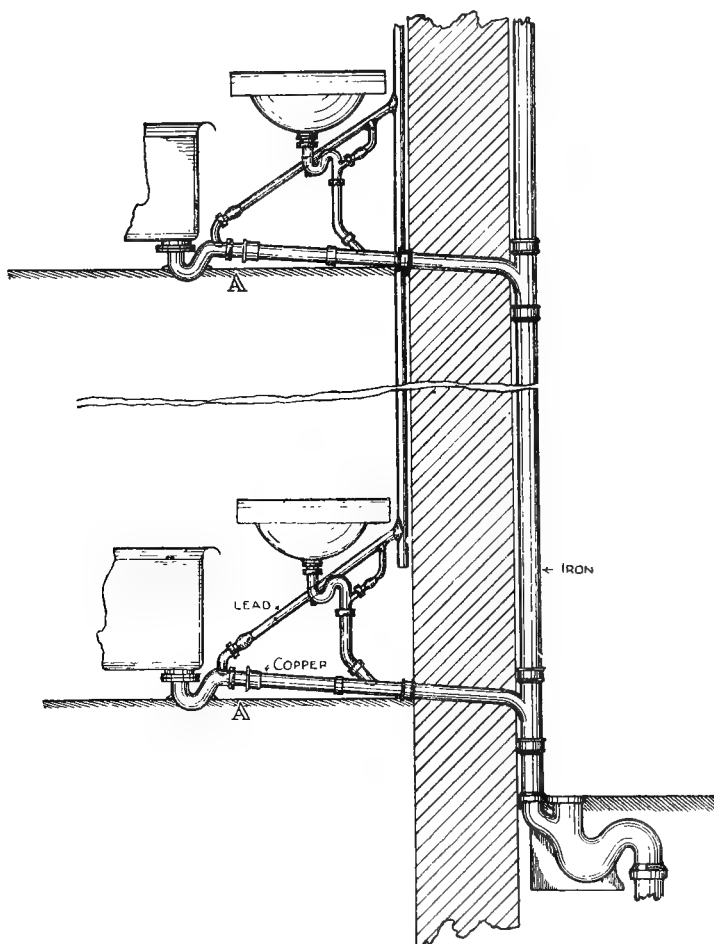


FIG. 125.—Arrangement of waste and of ventilating pipes in connection with baths and lavatories.

not be less than 2 inches diameter, whilst that from a lavatory should not be smaller than $1\frac{1}{2}$ inches diameter. Outlets from fittings should not be smaller than the waste

pipes used, otherwise the latter will not be properly cleansed, and may gradually choke up. The size of a main stack of waste pipes should be about 3 inches diameter, and in special cases a size larger may be necessary.

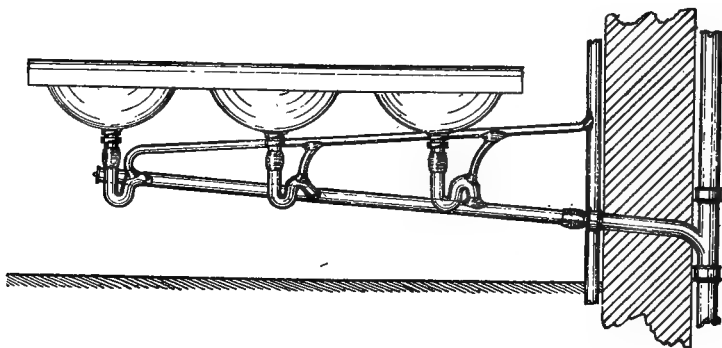


FIG. 126.—Arrangement of waste pipes for a range of lavatories.

Arrangement of Waste Pipes.—Figs. 126 to 128 show three different arrangements of lavatory waste pipes where the whole of the branch waste pipes and traps are supposed to be of lead; the main stack of pipes in each case is of iron.

Where a trap is placed beneath each lavatory the method

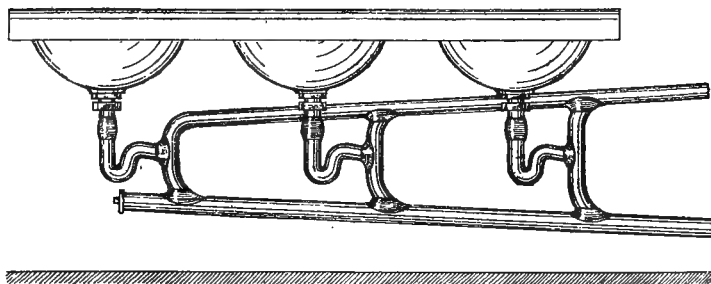


FIG. 127.—Arrangement of waste pipes for a range of lavatories.

of arranging the branches in Fig. 127 simplifies the work in connection with the antisiphonage pipes, and the long branch wastes may either be fixed above or below the floor. Provision should be made by means of thumb-screws for cleansing the long branches should a stoppage occur at any time.

In Fig. 126 the main antisiphonage pipe is shown on the inside face of the wall, but it may be placed outside if desired. Instead of having a separate trap under each fitting, a single trap for several fixtures is sometimes used, as in Fig. 128. The latter method is a cheap and simple one when compared with those of Figs. 126 and 127, and the short branches from each lavatory may be readily arranged to join at the side of the inclined waste pipe as in the figure given.

It is always desirable, where practicable, for the branches of either soil or waste pipes to join at the side, instead of at the top of a nearly horizontal pipe; side connections retard to a less extent the velocity of the discharging liquid, and the pipes are better flushed near the points of junction.

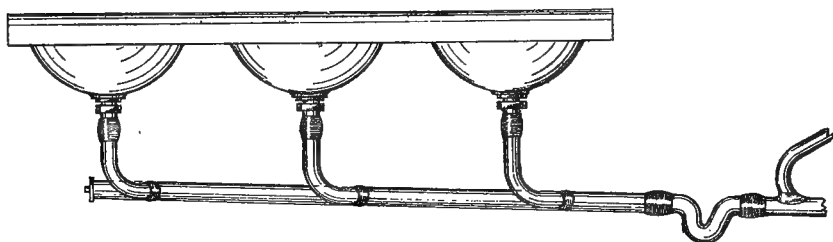


FIG. 128.—Arrangement of waste pipes.

As ranges of lavatories are required in large offices, schools, and other large buildings, it is essential that every precaution be taken to prevent foul air being emitted from them, and so proving injurious to the health of any individual.

Under most conditions a trap should be fixed immediately beneath each lavatory where a number are grouped together; this position for the trap, exposes the least amount of fouled pipe surface to the atmosphere of the apartments in which the fittings are placed.

When a range of lavatories is fixed in a well-lighted and detached building, which has ample permanent ventilation, and a compromise is sought between expenditure and hygienic considerations, the arrangement of waste pipes as shown in Fig. 128 is frequently adopted.

Another method of dealing with a group of lavatories, is to let each fitting discharge by means of a short pipe into a glazed fireclay channel immediately beneath them, the channel being laid to drain to a trap which is placed at any suitable point. This method of collecting the discharges from a range of lavatories is a very simple one, but from a health point of view it is bad in principle, for if the channels are neglected they soon get in a filthy state; the air which circulates through the short discharge pipes is also polluted by contact with their surfaces.

Sizes of Pipes for Ranges of Lavatories.—Single branches, as previously stated, should have a minimum size of $1\frac{1}{2}$ inch diameter; the horizontal branches should be from 2 to $2\frac{1}{2}$ inches diameter, according to the number of lavatories in a range. When the pipes are fixed as in Fig. 126, the short branch antisiphonage pipes which are joined with the traps may be 1 inch diameter; a suitable size for the horizontal antisiphonage pipe would be $1\frac{1}{2}$ inch diameter, which may be increased to 2 inches diameter beyond the eighth lavatory. In Fig. 127 each trap is branched into a short length of $1\frac{1}{2}$ -inch pipe, the upper end of which forms the antisiphonage pipe for each trap; with this exception the remaining sizes would be the same as for those in Fig. 126.

Slop Sink Waste Pipes.—Where discharges of hot water are allowed to flow through slop sinks, the whole of the waste pipes should be of iron or other hard, suitable metal. Special branches and connecting pieces should also be used to enable reliable joints to be made with the slop sinks. Owing to the contents of a pail being quickly discharged through these fittings, it is essential that special attention be paid to the sizes of the antisiphonage pipes where two or more slop sinks are discharged into the same stack of pipes. A suitable size for branch waste pipes is 3 inches diameter, and for a main stack 3 to $3\frac{1}{2}$ inches diameter. For a four storey building, where a slop sink is fixed on each floor, the branch antisiphonage pipes to each fitting may be 2 inches diameter, and for the principal antisiphonage pipe 3 inches diameter.

Waste Pipes for General Sinks.—Waste pipes for these fittings are often subjected to unfair usage, and although lead

waste pipes and traps are serviceable for many sinks, there are other cases where much stronger pipes and traps are essential. In places where waste pipes are likely to be subjected to rough usage they should be either of cast iron or brass, or of galvanised wrought iron. In ordinary dwelling and business houses short lead waste pipes answer admirably, but they often cause trouble if of considerable length.

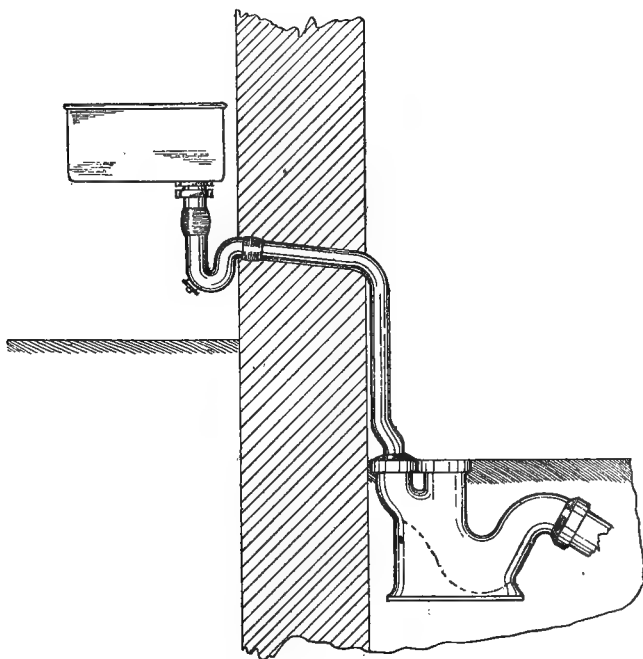


FIG. 129.—Waste pipes for sink.

Of course if very hot water is not discharged through them, long lead waste pipes are also durable.

Fig. 129 gives a waste pipe in connection with a scullery sink where the former discharges directly into a gully trap. The Model Bye-laws of the Local Government Board require a waste pipe to discharge on to an open channel which leads to a trapped gully grating at least 18 inches distant. The method suggested by the Bye-law is not a satisfactory one

as the open channel frequently gets filthy, or the water overflows it, whilst the force of the discharging water is lost.

No overflow is shown in Fig. 129, for, as stated elsewhere, sinks are better without them.

When a number of sinks discharge into a stack of waste pipes, and antisiphonage pipes are necessary, the latter should either terminate in the external air above the sinks, well removed from windows and ventilators, or be treated in a manner similar to that shown in Fig. 125.

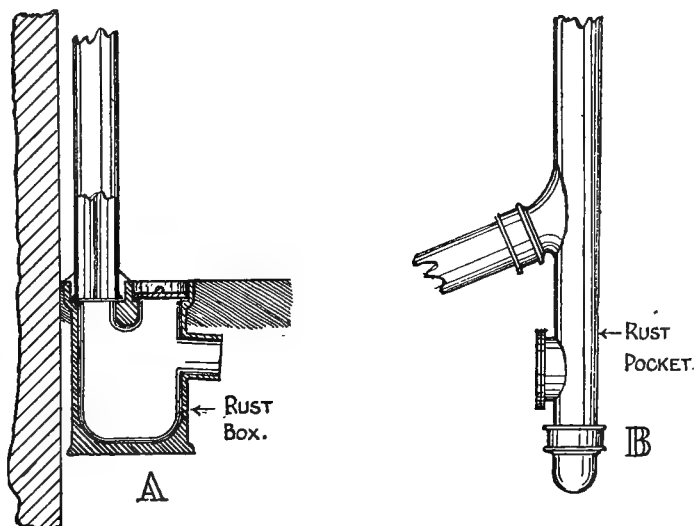


FIG. 130.—Rust pockets.

Rust Pockets.—When iron pipes are used for the purpose of ventilation, provision should be made for the interception and removal of rust.

For fixing at the foot of a ventilating stack, a rust pocket similar to A, Fig. 130, is suitable, whilst the arrangement at B, Fig. 130, may be adopted where bends are necessary in iron ventilating pipes.

Traps for Waste Pipes.—These traps are formed in different ways, and some of the types are very defective, being deficient in seal and constructed with sharp angles which retain filth. Unless traps are of a good shape they

unduly retard the outflow of water, and are liable to be frequently choked.

The water seals of traps for waste pipes should not be less than $1\frac{1}{2}$ inches deep, and as a rule they should not exceed 2 inches in depth for the large size of traps.

Three different forms of traps are given in Fig. 131, those at A and B being the best types at present in use. The outlet end of the siphon trap A takes different shapes to suit various situations, and this form of trap may also be obtained with long, straight outlet limbs when desired. A siphon trap is readily unsealed by momentum, but as the

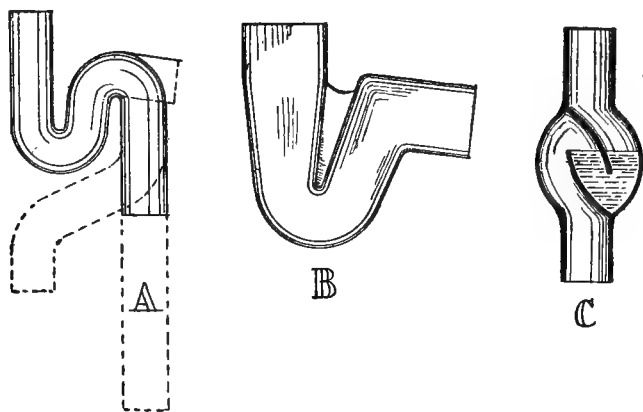


FIG. 131.—Forms of traps.

loss of seal by this action is chiefly confined to traps when fixed in connection with slop sinks, siphon traps are suitable for most of the remaining fixtures.

At B, Fig. 131, Hellyer's anti-D trap is given; the throat of the trap is restricted in area, and this enables it to be readily cleansed. In cross section its outgo is nearly square, the corners being rounded a little instead of being left sharp. Owing to the shape of the anti-D trap it requires to be cast, and although it is a little more costly than a drawn lead trap it is very much stronger.

The type of trap at C, Fig. 131, can only be described as a poor one. It usually has too shallow a seal, the depth of

which can neither be seen nor readily ascertained; the water passages are of a poor form, and the principal changes of direction are too abrupt.

Traps which have movable parts in the form of flaps or balls are not suitable for fixing to waste pipes; they are not reliable, and neither are they self-cleansing.

CHAPTER VIII

DRAINAGE OF HOUSES AND OTHER BUILDINGS

A DRAINAGE system should be designed upon sound principles, and constructed in a manner to prevent its being the cause of the pollution of the subsoil and a carrier of polluted air back to and into buildings. Numerous cases of typhoid fever and other illnesses—many proving fatal—have been attributed to sewage polluted water through defective drains. Sewer and drain air may also be the means of disseminating the germs of disease.

It is not intended here to deal with the different forms of old brick and stone built drains,—these being chiefly of historical interest,—but to devote the space at disposal to modern drainage work.

The value of a good drainage system is now generally appreciated, and for many buildings cast-iron drains are rapidly superseding those of earthenware for the conveyance of foul liquid matter. The substitution of iron for earthenware drains has chiefly arisen through the difficulty of maintaining the latter in a sound state for any great length of time after being laid and covered in. Very often it has been found that fine cracks have occurred at the sockets of earthenware pipes, due to the expansion of the jointing material, even when care has been exercised in carrying out the work.

When joints are made with portland cement they are very rigid, and if unequal settlement of the ground takes place the pipes readily fracture on account of their unyielding nature. When earthenware drains are laid, as they frequently are, with unskilled labour, and jointed with portland cement, there is little wonder that pipes and joints are readily broken,

especially when defects occur in work which has been well supervised and executed by experienced men.

As the failure of earthenware drains is frequently due to the use of portland cement as the jointing material, other substances, such as bituminous cements, which possess some degree of elasticity are now often used. In moderately firm ground, which is not subject to frequent vibration, earthenware drainage work may be satisfactorily carried out, provided a suitable elastic jointing material is used, and provided, further, that the pipes are of good quality and are properly laid.

The advantages of earthenware drains are their smoothness, freedom from corrosion, and the durability of the material.

Iron drains possess the merits of greater strength, reduced number of joints, and they can be made to remain air and water-tight for long periods after being laid. Spigot and socket joints should be used for iron pipes, and when the former are caulked with metallic lead they will yield a little should any slight settlement take place. Iron drains may occasionally be of a smaller diameter than those of earthenware, as the former may be obtained in a larger range of sizes, and may flow full and under pressure in suitable situations.

The chief drawbacks of iron drains are, their inner surfaces are not so smooth as those of earthenware, they are subject to corrosion, and therefore have a limited life. The initial cost of iron drainage work is also greater.

When dilute acids are frequently discharged into a system of drains, earthenware pipes and fittings are essential, as iron would be rapidly corroded. It is sometimes contended that an iron drain in connection with a residence is liable to be attacked by a periodical discharge of dilute acid, such as may occur when spring cleaning is proceeding. An iron drain, however, is not likely to be appreciably affected at such times, as the acid used would be in a very diluted state when it reached the drain, and the greasy surface of the latter would offer sufficient protection to the metal in most cases.

The minimum size of underground drain that is generally used is 4 inches diameter, but in many cases a 3-inch drain could be advantageously adopted for many branches. So far

as the capacity of a 4-inch drain is concerned, it is frequently capable of discharging a volume several times greater than it will ever be required to discharge. When the rain-water is separated from the foul-water drains, a 4-inch main drain would be large enough to dispose of the waste discharges from a very large building.

Definitions.—Foul-water drains are generally understood to be those which receive the discharges from any sanitary fixture in a building, waste water from wash-houses, and the dirty waste water which is discharged into gully traps.

Rain, or clean, water drains are those which receive rain-water directly from the roof of the buildings, and also subsoil water.

Drainage Design.—The chief points to consider when arranging a system of drains are:—

1. That they are laid with self-cleansing gradients.
2. That they are arranged in straight lines between fixed points, with true alignment of inverts.
3. That principal junctions and changes of direction are made in inspection chambers, to enable any part of a system to be readily accessible.
4. That every part of a system is adequately ventilated.
5. That the main drain is disconnected from the sewer.
6. That all levels be correctly obtained.
7. That after completion the drains will be capable of remaining water and air-tight.
8. That materials are of the best of their respective kinds.
9. That all drains are laid outside buildings where practicable.
10. That all unnecessary traps are avoided.
11. That the size of drains are proportionate to their requirements.
12. That all air inlets and outlets are located in positions well removed from windows and other places that afford a direct passage for drain air into buildings.

Fig. 132 represents the block plan of a detached villa residence, and a method of arranging the drains is also shown. Although the whole of the rain and waste water discharge into

one system, the length of foul-water drain is kept as short as practicable, and the whole system is shown as being well ventilated.

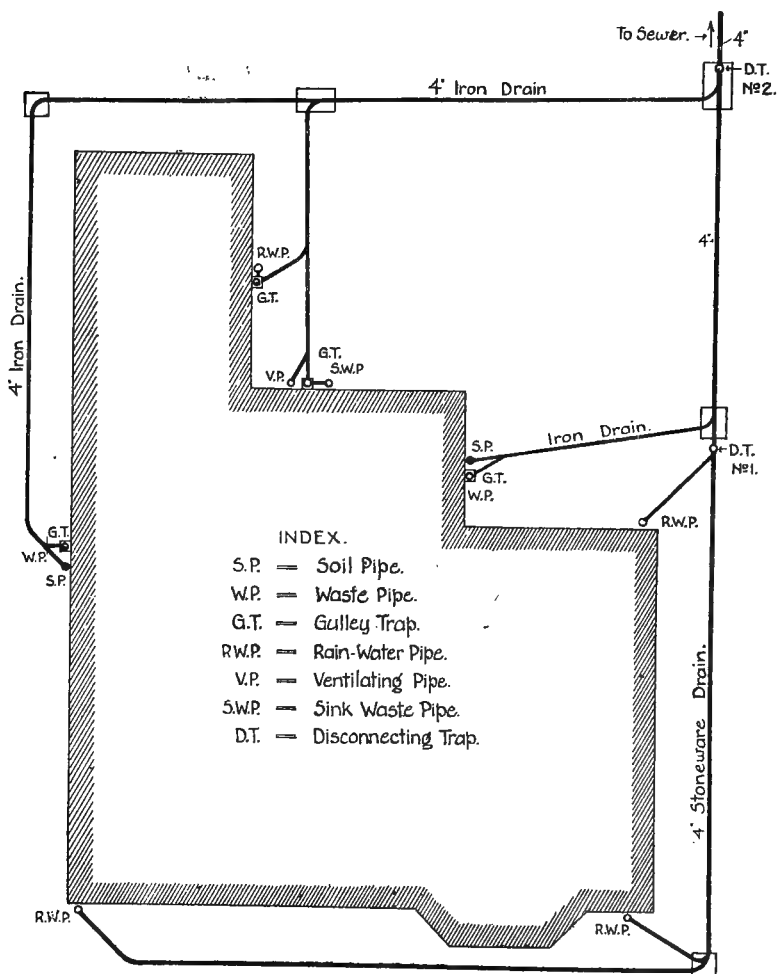


FIG. 132.—Drainage plan of a detached house.

The disconnecting trap No. 1 cuts off a length of earthenware rain-water drain from the foul-water system, and the

rain-water pipes in this case discharge directly into the branch drains. When a drain conveying clean water is disconnected from the foul-water drains as shown, a trap is not required at the foot of each rain-water pipe. In Fig. 132 there are two soil pipes shown, and it will be observed that each of these is arranged to come at the head of a section of foul-water drain, and to act as an outlet ventilator. The branch drain into which the kitchen sink discharges is ventilated by a special pipe, which is indicated on plan. It is intended in this case that the kitchen sink waste shall discharge into an ordinary gully trap, as a grease trap is not often necessary for a villa of the size shown. Where a waste pipe and a rain-water pipe are near to each other, they may both discharge into the same trap. All the chief lengths of drains in Fig. 132 are readily accessible by means of chambers, which are provided at the principal turnings and branches. A little consideration will decide the best positions for chambers, as their expense prevents their general use at all junctions and turnings.

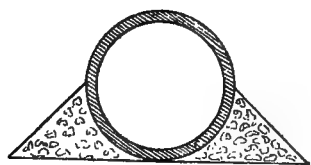
Drains should not be laid close to walls if it can be avoided, and where they do pass through them provision should be made to prevent the pipes taking any of the weight of the walls in case any settlement takes place.

In large buildings, and in terrace houses, where a drain discharges into a sewer in a front street, it is often imperative to lay drains through the buildings. In such cases it is desirable that provision be made to enable a stoppage to be removed without interfering with the floors of these places.

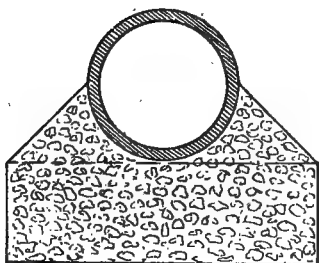
Drains under floors should be of heavy section cast-iron, but no concrete foundations are necessary for these pipes, provided that the ground is moderately firm on, or through, which they are laid.

Foundations for Drains.—When laying earthenware drains, concrete is often desirable, and in some cases its use is essential. Fig. 133 shows three different ways in which concrete may be used. At A an earthenware pipe is shown as laid in ordinary firm ground, where fine concrete is used for packing at the sides of the pipes after the latter have been jointed and tested. A fairly wide concrete foundation is indicated at B, Fig. 133, for poor ground, fine concrete being used as before for packing

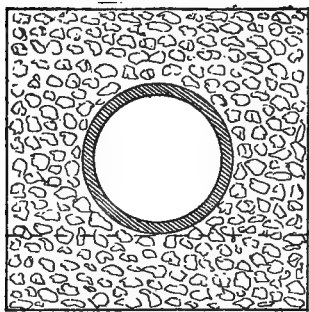
at the sides of the pipe. At C the drain is surrounded with concrete. This form of construction is necessary when earthenware



A



B



C

FIG. 133.—Foundations for earthenware drains.

drains are laid in deep ground, so as to take the weight of the earth, and also where they are laid near the surface of the ground which is subjected to heavy traffic passing over it. When foul-water drains are of earthenware, and are laid inside buildings, they should be well surrounded with concrete. The covering of drains with concrete adds greatly to their cost, so that where concrete is freely used, the difference between the cost of iron and stoneware drainage work may not be much.

It is necessary when laying pipes that they firmly rest on the ground for the whole of their length, for if pipes simply rest upon their sockets they are liable to be fractured by the superincumbent earth.

Connections with Drains.—

When a foul-water drain passes near to the foot of a stack of rain-water pipes, the latter frequently discharge directly into a gully trap, which is joined with the drain; if, however, a rain-water pipe is some distance from a foul-water drain, it should be treated as in Fig. 134. Here the rain-water pipe discharges

into an access bend, an iron grid being provided to enable air to flow freely in or out. The disconnecting trap should be fixed as closely to the foul-water drain as possible, in order

to limit the length of branch drain which is not subjected to direct ventilation. This method of treating the rain-water drains is also shown on the plan, Fig. 132.

The connection shown in Fig. 134 is often adopted for receiving the discharges from a lavatory, or similar fixture, which is located at the end of a long branch drain. As before, the disconnecting trap is joined with the nearest foul-water drain, but a solid cover is placed on the access bend instead of an iron grid. Air may then freely circulate

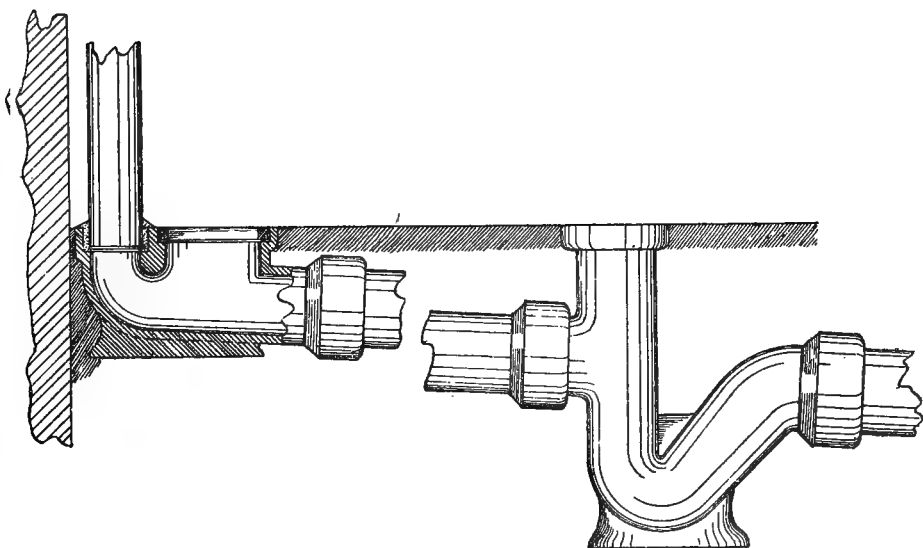


FIG. 134.—Connection between rain-water pipe and foul-water drain.

through the branch drain and waste pipe, the inlet side of the disconnecting trap serving as an inlet or outlet for air, as the case may be. By treating a stack of waste pipes in the manner stated, a separate ventilating pipe for the branch drain becomes unnecessary.

Junctions and Bends.—The junctions that should be used for branch drains are those having a curve towards the main channel in the direction of the flow. The V-shaped forms are also suitable. Right-angle junctions are often serviceable for testing purposes when suitably located, but they should

not otherwise be used, owing to the resistance they offer to the flow of liquids.

In general, bends should be made with a large radius, that changes of direction may be as easy as possible, sharper bends only being used in confined situations where the use of long sweep ones is impracticable.

Chambers and Openings for Access.—Chambers may be classified into two principal groups. (1) Those which are constructed with open channels, and require air-tight covers;

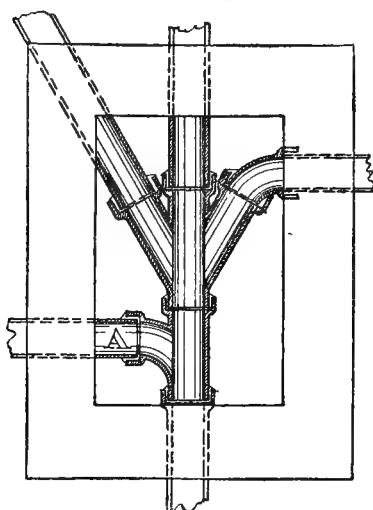


FIG. 135.—Plan of chamber when formed with stock fittings.

and (2) those which are formed with closed channels and are provided with suitable means of access, and where air-tight manhole covers are not essential. The first type possesses the advantages of the branch drains being under better control than in a closed system, (unless special fittings are used) and the inverts of the channels are exposed to view when the manhole cover is removed. The use of the first type is better suited for foul-water drains which are fixed outside buildings, and for rain-water drains.

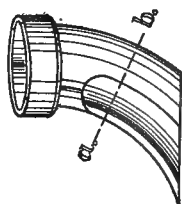
The second type of chamber is suitable for foul-water drains which are located close to and inside buildings, as no reliance is then necessary upon air-tight manhole covers and air-tight brickwork construction.

Where open channels are used for chambers inside buildings, any little defect in the sealing of the manhole covers admits a direct passage for drain air into the buildings.

In first class drainage work the inside face of a chamber is often formed with glazed bricks, and for work of a less costly character a sound red brick will often suffice, whilst a blue brick facing gives the happy medium. Open channels in

chambers are frequently formed of half pipes, half bends and junctions, but better channels are produced by having a chamber bottom in one or more pieces, according to its size. In Fig. 135 a plan of a collecting chamber is given, where the channels are formed from stock fittings. The chief drawback of this arrangement is, that when a discharge takes place through a branch like that at A, a portion of the water is liable to rush over the outer edge of the bend and up the benching, and thus destroy the effective flushing power of the water.

A better shape of channel bend, and one which prevents the drawback mentioned, is given in Fig. 136. Where a branch drain enters a main channel, the invert of the former should be higher than that of the latter, and for a main open channel to be satisfactory it requires to take a deeper form than the semicircular type. Fig. 137 gives a plan and part section of a collecting chamber, where the whole of the chamber bottom is formed in one piece of glazed fireclay; the branches, it will be observed, are arranged so as to concentrate the discharges into the main channel, but each chamber bottom requires to be specially constructed to suit the circumstances of each particular case.



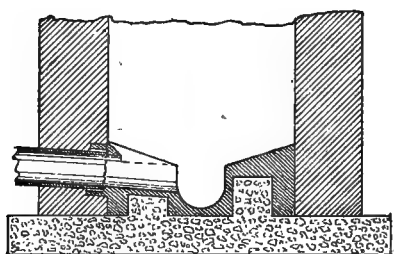
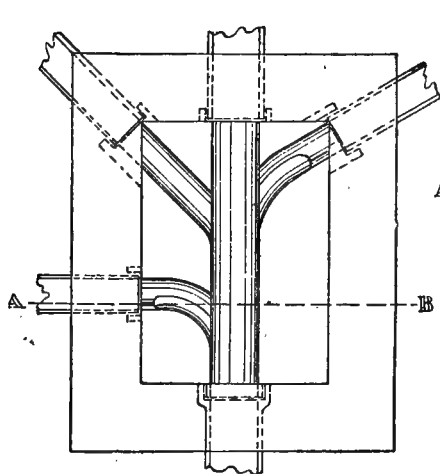
SECTION THRO a-b.
FIG. 136.—Channel bend.

When chambers are constructed with closed channels, the latter may be either of stoneware or of cast-iron, the design being similar in each case excepting that the methods of securing their access covers may differ.

A double branch piece for cast-iron drainage work is given in Fig. 138; the access opening should be as large as practicable so as to facilitate the inspection of the branch drains, and the cover may be secured by pinching screws and cross bridles, or by other suitable means.

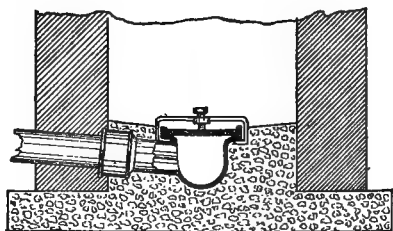
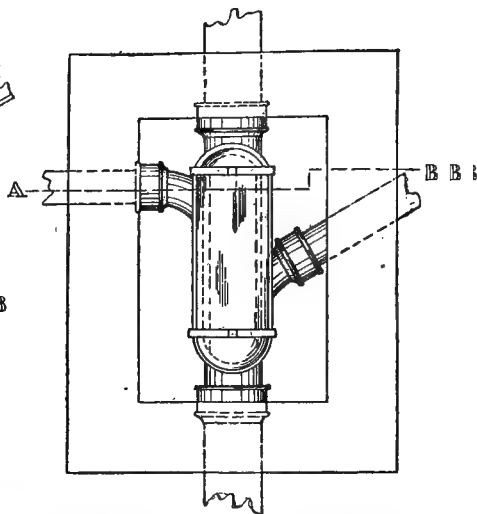
Sizes of Chambers.—The sizes of chambers are controlled by their depth and the number of branches which require to enter them; the minimum size of shallow chambers is about

2 feet square. Deep chambers, of course, must be large enough for a man to enter and to work inside them, so that the smallest size for the bottom of a deep chamber would be about 4 ft. by 2 ft. 3 in.; this size may be reduced to about 2 ft. 3 in. square or to other suitable dimensions for the top



SECTION THRO' A.B.

FIG. 137.—Plan of chamber bottom when formed with special channel blocks.



SECTION THRO' A.B.

FIG. 138.—Branch-piece for iron drain.

portion when about 5 ft. above the bottom of a chamber. In Fig. 138 the access junction rests upon a concrete foundation, and after the pipes have been jointed, gravel may be filled in and well rammed around the connections, the surface of the gravel being covered with a layer of cement mortar about 1 inch in thickness. A little space will require to be

left near the ends of the access openings, in order that the iron bridles may be removed.

A longitudinal section of an open channel disconnecting chamber with trap is given in Fig. 139. The trap should be placed immediately beneath the manhole cover, for if the former should get choked at any time it may be possible to remove the stoppage from the opening above. Iron stirrups should be built in the walls of deep chambers about 12 inches

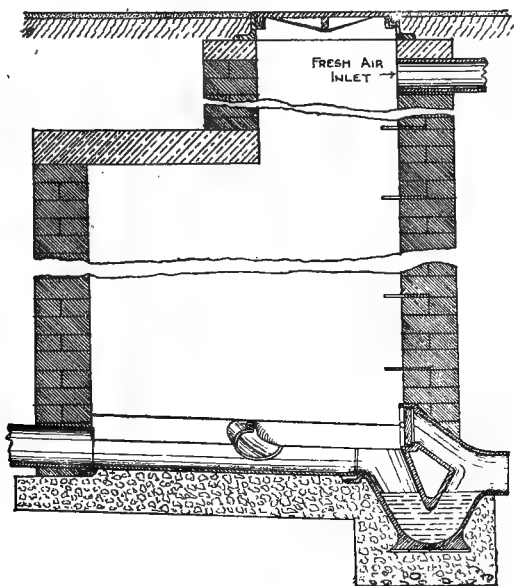


FIG. 139.—Longitudinal section through a disconnecting chamber.

apart to provide a permanent means for getting in and out. Where a raking arm is provided on the sewer side of a trap, as in Fig. 139, care should be taken that the stopper is properly secured, or the trap may be rendered useless.

Fresh air may be admitted to an open channel disconnecting chamber through a perforated cover when the chamber is favourably located, but it is often necessary to fix the fresh air inlet a short distance away from the manhole cover.

For iron drains, and where closed channels are used, a

similar disconnecting chamber to that given in Fig. 140 may be adopted. It will be observed that the invert of the channel in connection with the trap has a quicker gradient than that of the drain; this is very desirable, as the increased velocity imparted to the discharging matter compensates to a great extent for the resistance offered by the trap.

Manhole Covers for house drains are usually of cast iron, and many different patterns are made. For situations where heavy weights are likely to pass over them a strong section should be adopted. In public institutions, such as schools, it is often desirable to use covers which may be locked in order to prevent them being removed by children. Air-

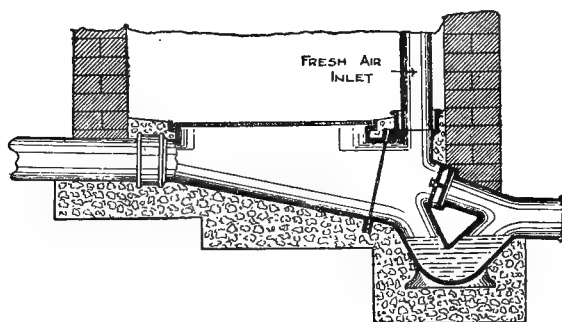


FIG. 140.—“Bland’s” iron channel and trap.

tight covers depend for their soundness upon tallow, oil, and similar substances; the frames of these covers are provided with grooves which are filled with the jointing material, and the rims of the covers are embedded into it.

Drain Traps.—The construction of traps for drainage work should be such as to offer the minimum resistance to the flow of liquids which pass through them; surfaces which are liable to be fouled should be of the smallest possible area, and all drain traps should be provided with large flat bases that they may be properly fixed. Many drain traps are little better than small cesspools on account of their size and the large volume of water they hold; such traps are most objectionable, as they are never properly cleansed and become very offensive.

A gully trap of good construction may be rendered faulty by waste water from sanitary fixtures first passing through a grating, instead of discharging directly into it, and in a direction that will thoroughly scour it out. For yards, and situations where a large amount of sand or fine gravel is liable to be washed into a trap, a self-cleansing type should not be used, but one similar to Fig. 141 is suitable, as any débris is retained at the bottom of the trap. Traps like Fig. 141 require to be cleaned out periodically, and their use is not desirable in

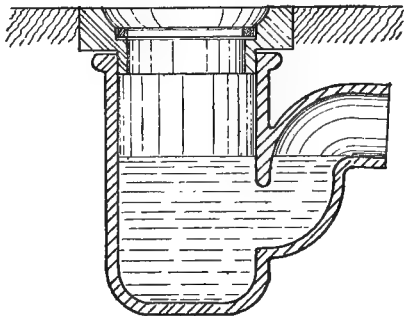


FIG. 141.—Trap for intercepting sand, etc.

house drainage work except for the special purpose stated.

Disconnecting Traps.—The object of a disconnecting trap is to break the direct passage between a drain and a sewer, but to leave a course through which liquid matter may flow.

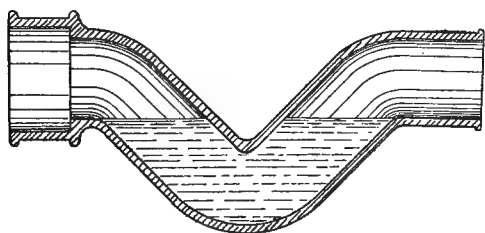


FIG. 142.—Poor form of disconnecting trap.

The value of a disconnecting trap has often been questioned, and its abolition would be advantageous to many engineers and surveyors, who are anxious to use the soil pipes of buildings

to aid in the ventilation of sewers. Although the disconnecting trap is not free from drawbacks, its retention is ensured for some considerable time, unless a more nearly positive method of drain and sewer ventilation to that generally adopted comes into force.

There are various forms of disconnecting traps, but they may generally be classified into three distinct types, as repre-

sented by Figs. 142 to 144; each type is made in both earthenware and iron. In Fig. 142 both the inlet and outlet are on the same level, and this type admits only of a sluggish flow through it, and is liable to retain a large amount of solid matter. The inlet of Fig. 143 is above the water-line of the trap, so

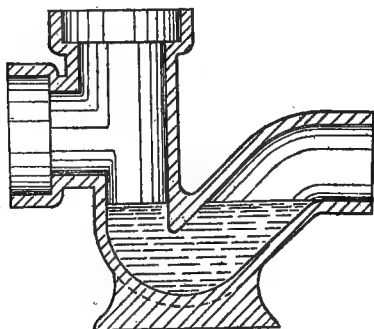


FIG. 143.—Buchan's disconnecting trap.

that the accelerated velocity of the discharge, due to the sudden fall, aids in scouring out the trap. When comparing Figs. 143 and 144, the shape of the latter at its inlet more nearly conforms with the path described by a discharging volume of water. A trap like Fig. 143 may in many cases allow a discharge to strike its opposite side, and so reduce

the effective flushing power of the water. The raking arm of Fig. 144 is also an advantage, as rods may be readily inserted and a stoppage removed on the sewer side of the trap.

The seal of a disconnecting trap should not be less than $1\frac{1}{2}$ inches deep, and a greater depth than 2 inches may be the cause of a stoppage taking place. Gully traps when placed at the bottom of rain-water pipes should have seals from 2 to $2\frac{1}{4}$ inches deep, and in special cases they may be increased to 3 inches on account of loss by evaporation in periods of drought.

Grease Traps are of two principal types: those which

require the grease to be removed from them periodically by hand, and those from which grease is automatically discharged through drains by the aid of flushing water.

Fig. 145 shows the first type of grease trap, whilst a

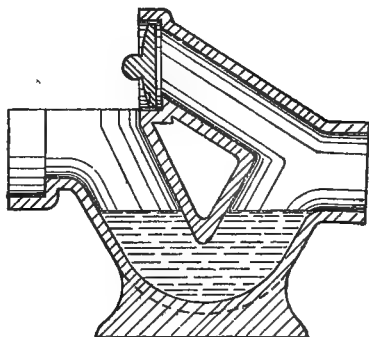


FIG. 144.—Disconnecting trap.

flushing type is illustrated in Fig. 146. As a rule grease traps are filthy receptacles, and should not be used unless absolutely necessary. For private houses they are seldom

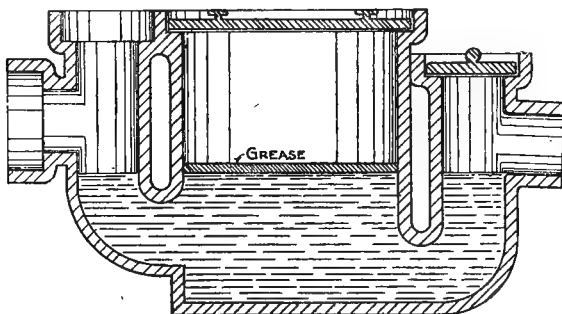


FIG. 145.—Buchan's grease trap.

required, but are often essential in large hotels, restaurants, and similar places, where a large amount of greasy matter is discharged into the drains. Grease traps to fulfil their purpose

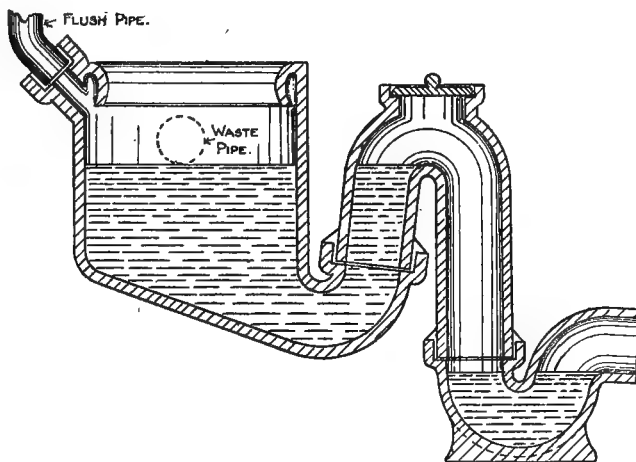


FIG. 146.—Adams' flushing grease trap.

require to hold a large volume of water, in order to solidify the hot liquid grease as it enters them; when the volume of water is comparatively small in a grease trap, there is danger of the trap being rendered useless by its contents

getting overheated, and by the grease flowing into the drain in a liquid state.

In the flushing type of trap the grease is discharged through the drain in a solid state, for in this form it is not likely to cause any trouble. Many flushing grease traps, however, are too small to serve any useful purpose, and such fittings are often fixed where an ordinary gully trap would be preferable.

Tidal Traps.—In low-lying districts, where sewers discharge into tidal rivers, or into rivers which rapidly rise in time of storm, the basements of buildings in such areas are

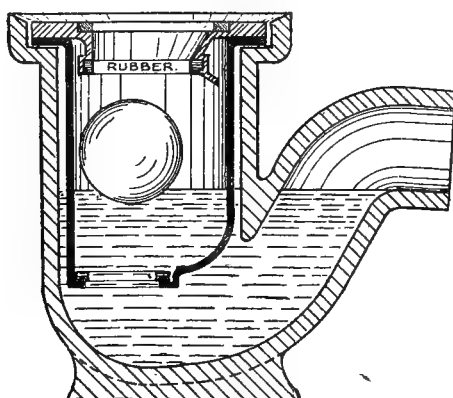


FIG. 147.—Couzen's tidal or anti-flooding trap.

subject to periodical flooding unless means are taken to prevent it. The back flow of water through drains may be arrested in different ways, such as by fixing simple flap valves at the ends of the drains where they join the sewers, or at convenient points in the drains themselves. The flaps are hinged, and swing outward when a discharge takes place from a drain to a sewer; but a return flow presses the flap on to a seating, which if properly arranged makes a water-tight joint. As galvanised iron or other metallic flaps are liable to stick or otherwise get out of order, ball traps similar to those shown in Figs. 147 and 148 are preferable. Strong copper balls are used in these traps, and a back flow of water presses the balls on to rubber-faced seatings. The trap shown in Fig. 147 is suitable

for fixing in a basement area or similar situation, whilst the disconnecting type of trap, Fig. 148, is better suited for receiving several branch drains to which ordinary gully traps are joined. A chamber of ample size should be constructed for the latter type of trap, to enable the covers to be removed when required.

Other forms of tidal traps are used, but those shown are the most reliable types.

Drainage of Basements and Sewage Lifts.—Speaking generally, the drainage of a basement in an ordinary dwelling presents no special difficulty. Where a basement is used as a wash-house, provision is of course necessary for disposing of

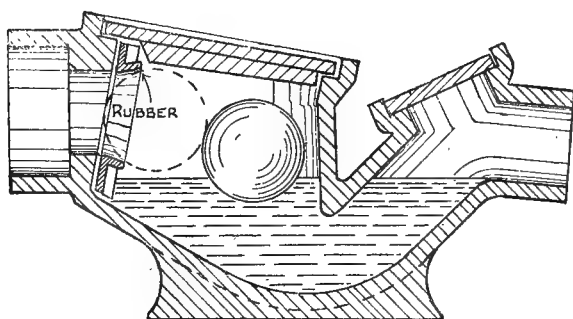


FIG. 148.—Couzen's tidal or anti-flooding trap.

the waste water. The most efficient method of doing this is to provide an outside area in which a gully trap is fixed, and to make the floor of the cellar fall towards the area; this arrangement dispenses with the use of a trap in a basement floor, and in the event of the area trap being unsealed by evaporation, drain air may not directly escape into the basement, but the greater portion may rise through the area grating and become diffused with the outside atmosphere. That, however, would be largely governed by the state of the external air with respect to its temperature and humidity.

In many large buildings with basements and sub-basements, the liquid waste matter first requires to be raised to a higher level before it can be discharged by gravity into a sewer. For such buildings the waste discharges from the upper storeys

should be conducted in the usual manner to the sewers, thus only leaving the sewage that is discharged at the lowest levels to be dealt with.

Appliances for raising sewage may take various forms, such as pumps (which may be worked either by hand, steam power, water power, or electricity), ejectors, and sewage lifts, etc.

The most suitable method to adopt chiefly depends upon the power available, the nature of the waste liquid, and the volume to be raised. Where only small volumes of waste matter require to be dealt with, a suitably arranged sump and a small hand-pump might be adopted. For dealing with larger volumes of sewage a water motor and plunger pump could be installed, and also be arranged to be automatic in action. The sewage could also be handled by an electric motor and centrifugal pump, or if steam were available a pulsometer could be used.

Adams' lift, Fig. 149, is suitable for raising sewage in certain cases, such as where the water to work it may afterwards be utilised for supplying sanitary fixtures, etc., at a lower level, or where the cost of water is small. The apparatus Fig. 149 consists of the following parts: an automatic flushing tank A, a cylinder B, siphon C, a sewage cylinder D, an air pressure transmitting pipe E, a non-return valve F, and a sewage receiver G. Assuming the apparatus to have just discharged, and the automatic flushing tank A refilling, the cylinder B would be full of air at atmospheric pressure on account of the open pipe H being joined to the flush pipe. Sewage flowing from sump G enters the sewage cylinder D, but is prevented from returning by the non-return valve F. The action of the apparatus is as follows: When the flushing tank A is full of water, its contents are automatically discharged into the cylinder B; as this cylinder fills with water, its confined air is compressed, the air pressure being transmitted by means of pipe E to the surface of the sewage in the cylinder D; in this manner the sewage is displaced from the cylinder through the outlet pipe P into the chamber shown; from the chamber the sewage gravitates to the sewer. The water is discharged from cylinder B by means of the siphon C, the capacity of the flush tank A being sufficient

to fill cylinder B and to charge the siphon as well. The tank B may be placed in any convenient position, but the head of the flushing tank will require to exceed the height to which sewage is to be raised. The outlet leg of the siphon C is

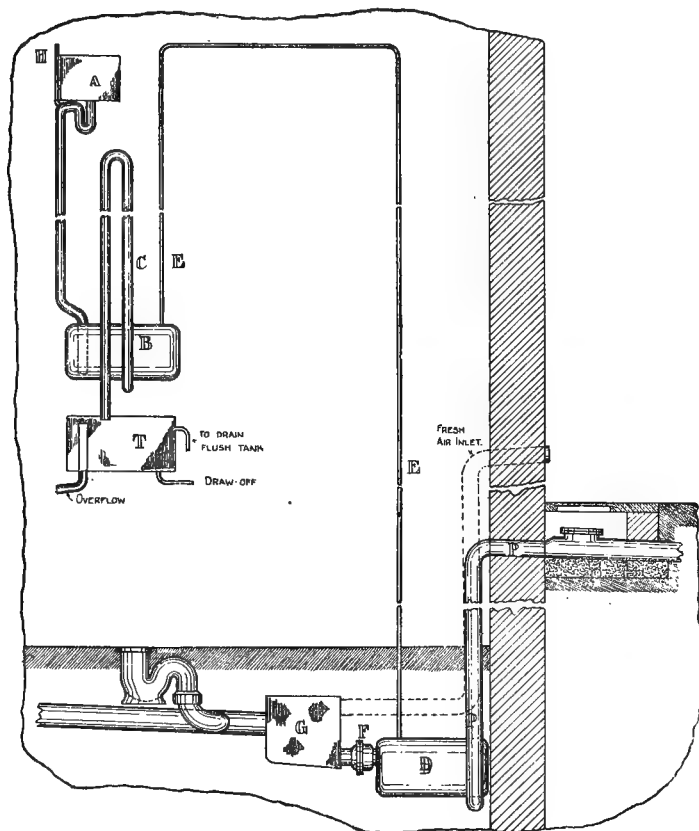


FIG. 149.—Adams' lift.

shown discharging into a clean-water storage tank, from which the water may be withdrawn as desired. A suitable overflow pipe would be necessary for tank T in order to carry away any surplus water.

Such surplus water could be utilised for flushing drains by

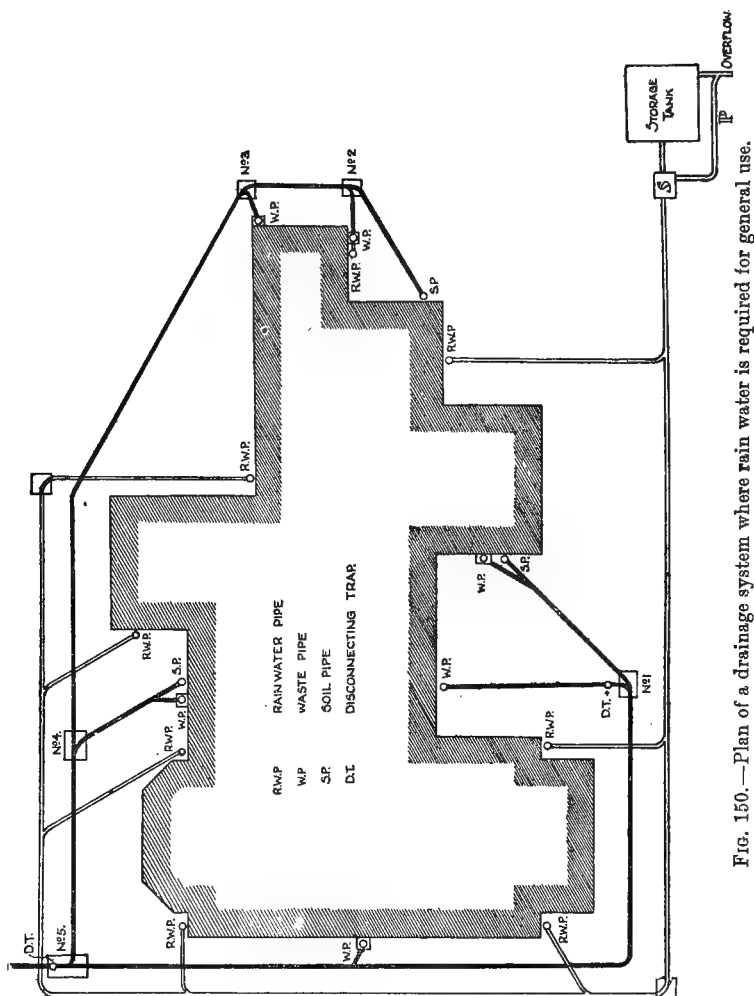
joining a pipe with tank T, just beneath the overflow, in order to supply an automatic flushing tank at a lower point.

A fresh air inlet pipe is shown joined with the sump G, and an air outlet is supposed to be provided at the head of the drain. When water is raised from a low to a higher level and it is not of a very foul nature, it may be discharged into a gully trap, instead of into a chamber as in Fig. 149.

Fig. 150 shows the drainage system for a large house, where the greater portion of the roof water is conducted to a storage tank. The sewer is supposed to be at the front of the house, whilst a storage tank, together with rain-water separator, is located at the back. The whole of the foul-water drains, with the exception of a few very short branches, is made accessible by chambers, and the head of each section of foul-water drain has a suitable outlet ventilator. Instead of showing a trap at the foot of the waste pipe where the drain from same delivers into chamber No. 1, a disconnecting trap is placed near this chamber, and the length of branch drain ventilated by means of the waste pipe which is supposed to be carried full bore above the eaves. Where the branch drains are short, gully traps are indicated for receiving the discharges directly from the waste pipes, and a trap is better located at the foot of a waste pipe unless it is the cause of a length of drain being without adequate ventilation.

As the greater portion of the rain-water drains is separated from the foul-water drainage, no traps are necessary for this section, and ordinary access bends may be used at the bottom of the rain-water pipes. Access bends, along with the chambers shown, render the rain-water drains readily accessible. The rain-water separator S, Fig. 150, prevents the first portion of the rainfall from entering the storage tank, and diverts it through the by-pass P into the overflow from the tank. The tank overflow is supposed to discharge into a water-course or other suitable channel, but assuming it were necessary for it to discharge into the sewer, then the overflow could join with chamber No. 2. A disconnecting trap would of course be essential on the overflow, and one with a specially deep seal would be preferable unless measures were adopted to keep the trap fully sealed. If it were necessary for the overflow from

the tank to discharge into the drainage system as suggested, chamber No. 2 and the drain from it would require to be deeper than with the arrangement shown; under such con-



ditions the disconnecting chamber No. 5 might be better located at the right side instead of at the left side of the house, as in Fig. 150. The position of the disconnectin

chamber should be controlled as far as practicable by the depth of the drains so as to minimise cost.

The whole of the foul-water drains are assumed to be of cast-iron, and are indicated by bold lines; stoneware pipes would be used for the rain-water drains, and these are indicated in double lines.

Drainage of Stables and Byres.—Stables are better drained by means of open channels in the floors, the channels being arranged to discharge into one or more traps which are located near the walls in the open air. Traps inside stables should be avoided if possible, but if their use is found desirable, good strong iron traps with hinged grids should be used. Open channels should be as shallow as practicable, and so formed that there is no likelihood of them tripping and laming a horse. In some cases channels in stables are covered with iron grids, but these are often more objectionable than traps, for unless the grates are regularly taken up and cleansed they get into a very unsatisfactory state. Channels when exposed to view are as a rule kept in a more cleanly state than those which are covered with grates.

The method of disposing of the liquid waste matter from stables will largely depend upon the location of these buildings. Where land is available the urine should drain to a suitable sump, that it may be periodically applied to the land. In other cases where no land is available, the discharges from stables may require to flow into a sewer. For stables where the urine is utilised for its manurial value a separate system of drains is required to deal with the waste water, and also that from roofs and paved surfaces. The underlying principles for stable drainage, however, are practically the same as those which govern house drainage work.

It is usually desirable to disconnect stable drains from those of dwellings, so that they may be ventilated independently of each other.

The drainage arrangement for byres is similar to that for stables, but the constructional details differ with respect to the formation of the floors and channels.

Connections of Drains with Sewers.—When pipe sewers are laid, junctions are provided at intervals to receive the

drains from existing property, and also to a great extent for properties to be erected at a future date. Many cases occur, however, when a connection with a pipe sewer is necessary and where no provision has been made. In earthenware sewers junctions cannot be properly fixed after the pipes are laid unless three or four pipes are removed, or unless special forms of junctions are used. The removal of say three lengths of pipe during a constant flow of sewage creates some trouble, and often one pipe only is removed for the insertion of a junction. In such a case, when an ordinary junction is used it is necessary to shorten it, in order to get it in position; by this method both joints of the main channel

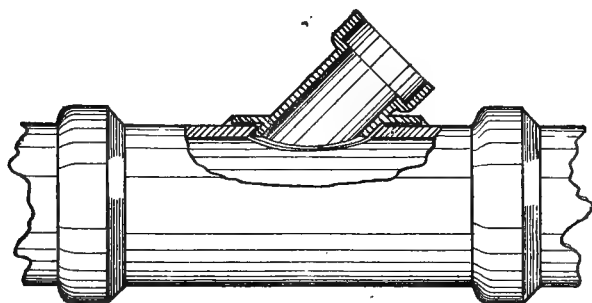


FIG. 151.—Socketed saddle piece for making a connection with a sewer.

are only at the best half socketed, and the cavities remaining fill with putrid matter.

For making a branch connection with an existing pipe sewer, a hole may be cut into the side of the pipe, and a socketed saddle piece arranged as in Fig. 151. The saddle piece is provided with a curved flange, and when properly jointed and supported good connections can be made without disturbing the principal line of pipes.

To connect a drain with an existing brick sewer, a proper junction block should be used as in Fig. 152; the bricks require to be carefully cut away, the block inserted, and the brick work again made good. Junction blocks are made in glazed stoneware for either $4\frac{1}{2}$ -inch or 9-inch brickwork, and to suit different sizes of sewers. It is necessary to insert a junction block well up on the side of an egg-shaped sewer in order that

the end of the drain, shall not be submerged with rather more than the normal flow of sewage. A length of drain which is partially submerged soon begins to silt up.

Ventilating and Flushing of Drains.—The object of ventilating drains is to prevent the accumulation of dangerous gases in them, and to dilute any gas as generated with large volumes of atmospheric air. The flushing of drains is closely allied with their ventilation, as this prevents putrid matters lodging in drains and keeps them in a cleanly state.

In many cases the ventilation of drains is a simple matter, but in others it is more difficult to carry out owing to

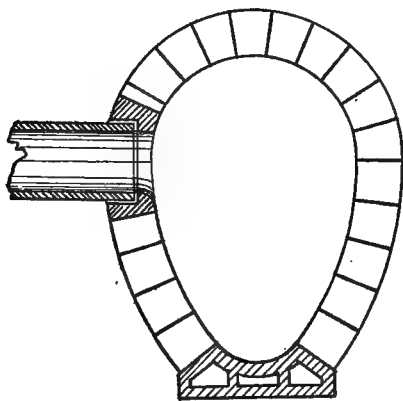


FIG. 152.—Connection for a drain and brick sewer.

unfavourable situations for air inlets and outlets. Where only natural forces are engaged in drain ventilation, the air cannot be regulated to flow at all times in one particular direction. In many cases the air currents are often reversed, and there are also periods when ventilation is nearly stagnant.

For a villa residence, where the fresh air inlet of a drain may be suitably placed in a garden some

distance from the building, it matters very little whether the air currents in the drains are frequently reversed or not. Where, however, the front and back of a building join with main thoroughfares, as is the case with many city buildings, the effect of reversed currents in drains is of more importance, and a method of drain ventilation may be necessary where foul air cannot escape at a low level.

Fig. 153 gives a method of ventilating the drains for the latter class of building. At the back a soil pipe is represented, and at the front of the building a low-level fresh air inlet is shown, which is joined with a high-level ventilating pipe. To the fresh air inlet a reliable form of non-return

valve requires to be attached, to prevent drain air escaping at that point when the air currents in the system are reversed. The ventilating pipe, which is carried up the front of the building, serves either as an inlet or outlet for air, and it also prevents the air in the drain being put in a state of compression when the inlet valve is closed, and when a large volume of water is being discharged from a high level into the drain.

In drain ventilation the air should be able to flow freely in

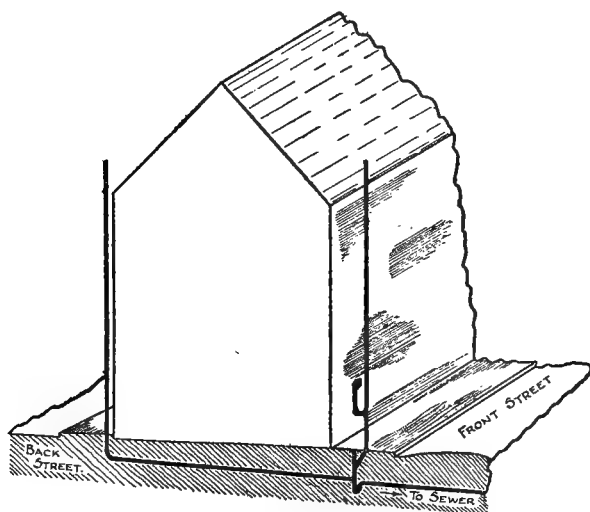


FIG. 153.—Drain ventilation.

either direction, and at the same time it should not be allowed to escape at any point where it may prove disagreeable or injurious to health.

There should always be a marked difference between the levels of inlets and outlets in drain ventilation, for where only high-level inlets and outlets are used ventilation is often stagnant.

The flow of air through drains is affected by the following: Relative humidity of the atmosphere, the number of bends in drains and ventilating pipes, difference between internal and

external temperatures, force of the wind, and the arrangement and location of fresh air inlets and outlets.

It is often assumed that air flows with more or less considerable velocity through drains, and that a ventilating stack acts something like a chimney. The flow of air through drains, however, is often very sluggish, on account of the resistance which the air encounters.

The humidity of the atmosphere has a marked effect on drain ventilation, and when the atmosphere is in a state of saturation, or when its percentage of humidity is high, ventilation is often at a standstill, whilst with a dry atmosphere, other conditions being equal, it is usually active.

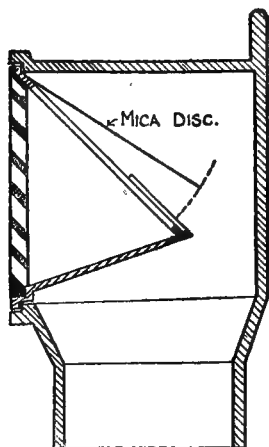


FIG. 154.—Barker's fresh air inlet valve.

Heat and cold have their effect; in winter many ventilating pipes which are exposed to the cold are readily converted from outlets into inlets, owing to the air in the pipes being heavier than that in the drains.

Retardation of the flow of air due to bends is often considerable, and most forms of cowls are also offenders in the same respect. For drain ventilation, cowls should not be used, as they more frequently retard the flow of air than accelerate its movement.

The extracting power of the wind is not always fully utilised in drain ventilation, as much depends upon the position of the outlet ventilators.

A good form of mica flap air inlet valve is given in Fig. 154.

Flushing Drains.—To keep a drain in a satisfactory state of cleanliness, it is occasionally necessary to resort to flushing; this may arise through the character and volume of the waste liquids discharged, or to the gradient of a drain being inadequate to produce a self-cleansing velocity.

In order to cleanse drains, automatic flushing tanks are generally installed at suitable points, to enable large volumes

of clean water to be rapidly discharged into the drains. These tanks take different forms, but they may be divided into the following types:—

- (a) Those which are provided with “vacuum” action siphons, and will work with a slow feed.
- (b) Those with “plenum” siphons, and which also will operate with a slow feed.
- (c) Those with siphons and reversed action ball cocks, and which require a quick feed just prior to their discharge.
- (d) Those with mechanical parts, such as tipplers, floats, valves, etc.

Automatic flushing tanks are constructed of galvanised iron, and of concrete or brickwork; the former are suitable for fixing inside buildings, whilst the latter are suitable when they require to be placed below ground level.

Fig. 155 gives Rodger Field's automatic flushing tank, which is representative of type *a*. At the top of the stand-pipe *P* a short taper pipe *C*, which forms an inverted frustum of a cone, is attached; the outer covering or dome *D* contains an air-hole

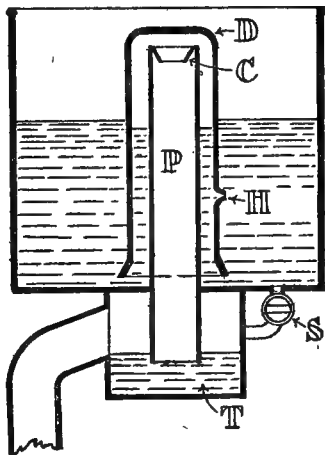


FIG. 155.—Field's automatic flushing tank.

H, and a trap *T* is formed with a small seal by submerging the end of the stand-pipe. The action of the siphon is as follows: When the water in the tank is above the air-hole *H*, air is confined in the upper part of the dome and stand-pipe; as the filling of the tank proceeds, the confined air is further compressed, until it overcomes the resistance offered by the water seal of the trap, when small volumes of air escape. Each time an escape of air takes place, the water rises higher in the annular space between the dome and the stand-pipe, until it finally reaches the top of the latter and overflows; the water upon falling through the stand-pipe gradually dis-

places some of its confined air, and after a time the air pressure in P is so reduced that it is no longer capable of resisting that of the external air, when the discharge is started and the water siphoned from the tank.

The purpose of the inverted frustrum C is to make the water fall clear of the sides of the pipe, for if it merely trickled down the sides no displacement of air would be effected, and the siphon would not be brought into action.

The air-hole H is necessary to break siphonage at the end of a discharge, and when it is omitted or choked, water is liable to be withdrawn as quickly as it enters the tank, after once siphonage has been established.

A vacuum action tank will also get out of order if the interval between the flushes is very prolonged, owing to the loss of air from the stand-pipe. The effect of this loss is to allow the water to dribble away as quickly as it enters a tank when once the latter is full.

A by-pass with a stop-cock S, Fig. 155, is often provided for this class of tank, so as to enable the water to be discharged when the tank is out of working order due to loss of air.

Adams' plenum action automatic siphon, Fig. 156, is shown fixed in a brick tank, and illustrates the general principles embodied in type *b*. The construction of plenum siphons by different makers differs a little in details, such as in the provision made for starting, stopping, and charging the siphons, but all require deep seals, the depth of which is regulated by the depth of water desired in the tanks.

The action of the siphon in Fig. 156 is as follows:—After water has risen in the tank above the end of the tube T, air is confined in the long vertical leg P of the siphon; the gradually increasing head of water transmits pressure to the confined air, which in turn begins to displace the water from P, and through the outlet of the siphon. When a predetermined water-line has been reached in the tank, the level of the water in the stand-pipe will be down to the lip L, when with the further filling of the tank a volume of the confined air is displaced from P, followed by water, and the siphonic action as a consequence started. At C, Fig. 156, the diameter of the outgo is contracted in order that the air shall be

discharged clear of the sides of the pipe, and aid in the starting of the siphon by reducing the resistance in the outlet leg. The tube T serves the double purpose of confining the necessary amount of air in the siphon, and of effectively breaking siphonic action after the period of discharge.

Type c automatic flushing tank is illustrated by Fig. 157, and is provided with a reversed action ball-cock; a small bib-cock is often used to regulate the filling of the tank, and when the latter is nearly full the ball-cock is opened full bore, and

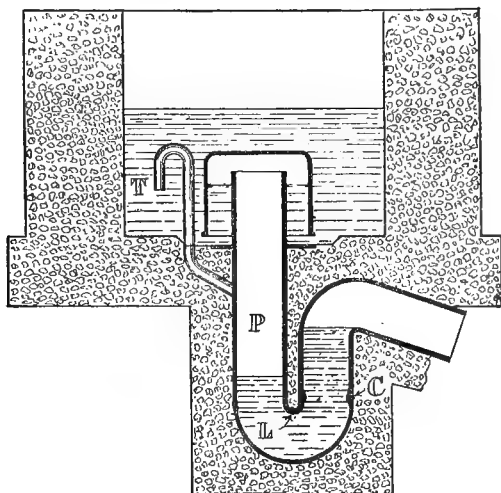


FIG. 156.—Adams' automatic flushing siphon.

the siphon is charged and brought into action. The automatic siphon Fig. 157 would be useless with a slow feed when nearing its point of discharge, as a slow inflow of water would be unable, owing to the form of the siphon, to dislodge sufficient air from it. A rapid inflow, however, when the tank is nearly full, dislodges the air, and siphonage is established.

In order for all forms of automatic siphons to work properly they must have a free discharge, and no air must be confined in their outlet pipes.

The tipper tank Fig. 158 is provided with trunnions, and depends for its action upon the shifting forward of its centre

of gravity when the tipper is filled with water; this causes the tipper to cant forward and discharge its contents, when it again rights itself owing to the centre of gravity of the empty tipper

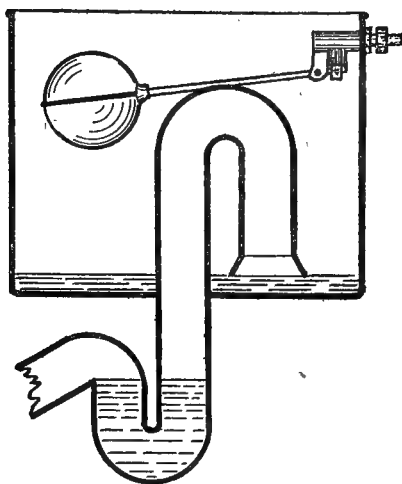


FIG. 157.—Automatic flushing tank.

being again moved nearer the back, which is occasionally weighted. Tipplers are very noisy in action, although this can be largely counteracted by providing buffers against which they may strike.

Flushing tanks similar to Fig. 158 are simple in construction, but they are liable to get out of working order owing to the wear on the trunnions.

The length of drain which can be adequately cleansed with an automatic flushing tank will depend

upon the gradient of the drain, upon the initial velocity of the flushing water, upon the condition of the drain, and upon the volume of water and size of siphon used.

To give the discharging water a high initial velocity, the flushing tank should be fixed a few feet, where possible, above the drain to be flushed. The velocity with which the discharge enters a drain is soon diminished, and gradually decreases, until it finally acquires that due to the gradient of the drain. Decline of velocity and flushing power, however, do not take place at a uniformly decreasing rate, but is greatest per unit length of drain where the velocity is highest.

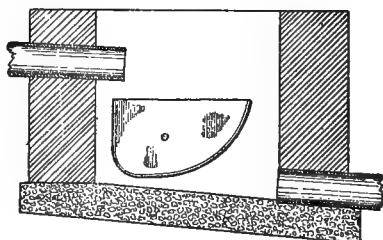


FIG 158.—Tipping flusher.

It is desirable when drains are very long, and where flushing

is necessary, to provide tanks at two or more points which are some distance apart, rather than to discharge their combined volumes into a drain at one point.

Rain water may be utilised for flushing drains in many cases by constructing a suitable tank for the purpose.

The following table gives sizes of siphons and volumes of water necessary for flushing drains.

TABLE II.

Size of drain to be flushed.	Size of Siphon.	Capacity of flush tank.
4 inches diameter.	3 inches diameter.	25 to 40 gallons.
5 " "	3½ " "	40 " 60 "
6 " "	4 " "	60 " 80 "
8 " "	4½ " "	80 " 120 "
9 " "	5 " "	120 " 180 "

Methods of Laying Drains to given Gradients.—After the plans have been prepared for a drainage system, levels may be taken and sections prepared which show the gradients and depth of drains. For a small system which discharges into a sewer of ample depth plotted sections may be unnecessary, but their use is practically imperative for large drainage systems. The depth of drains is greatly increased where basements require to be drained, but a system should be designed as far as possible to avoid unnecessary lengths of deep drains.

Different methods are adopted for obtaining true alignments of drains between given points, such as by the use of (*a*) chalk lines, (*b*) straight edges, (*c*) sight rails and boning rods.

Chalk Lines.—When a chalk line is used it is often placed against the sockets of the pipes, midway between the top and one side, so as to serve the purpose of testing the straightness of drains in two directions at the same time. A method of giving a length of drain a given gradient where a level is not used, is to drive in the ground a strong wooden-peg at each end of the excavated track; the peg at the higher end is driven so as to leave its top level with the bottom of the pipe. One end of a long parallel straight-

edge is then placed on the peg, and by the aid of a spirit level the straight-edge is set level. A chalk line is afterwards tightly stretched from end to end of the track, so as to just rest on the top of the straight-edge for the whole of its length. In this manner at the lower end of the track a point is obtained which is in line with the top of the straight-edge in question. If now at the lower end a peg has been used of sufficient length, the level obtained by the chalk line can be marked upon it. The lower fixed point for the gradient is then obtained by deducting from the mark already on the peg the height through which the drain must fall, plus the width of the straight-edge. When the latter point has been measured off, the upper portion of the peg can be sawn off, so as to make its top level with the bottom of the drain. After the first drain pipe has been placed in position, another pipe may be temporarily laid in its place at the higher end, and the chalk line stretched between them.

A drawback, however, which attends the use of chalk lines is their liability to sag, and thus give more or less irregular gradients.

Short Straight-Edges and a spirit level are sometimes used for laying drains. In this case either parallel or tapered straight-edges are used, the latter being made to agree with the gradients of the drains. This method is less satisfactory than the first one described, as each pipe is fixed only with respect to that previously laid, and deviation from the correct gradient may readily occur.

Boning Rods and Sight Rails.—The best way of obtaining true gradients is by the use of sight rails and boning rods. Sight rails are placed across the trench, and consist of two strong vertical posts which are securely fixed in position, with a horizontal cross-piece attached. A boning rod represents a rough form of T square, with an iron shoe or stirrup at its lower end for laying on the inverts of the pipes. Boning rods may either be made in adjustable forms, to enable their lengths to be increased and shortened as desired, or constructed with upright pieces in one length.

The usual method of fixing sight rails is shown in Fig. 159, where the uprights are fixed in drain pipes and held in position

by ramming the latter full of earth. A sight rail is fixed at each end of a straight drain track, and when the latter is very long, intermediate sight rails may be fixed at intervals of about 60 to 80 yards. It is essential that sight rails be fixed in positions which are not liable to be disturbed by subsidence, or be moved in any other irregular manner.

A front and side view of an adjustable boning rod are

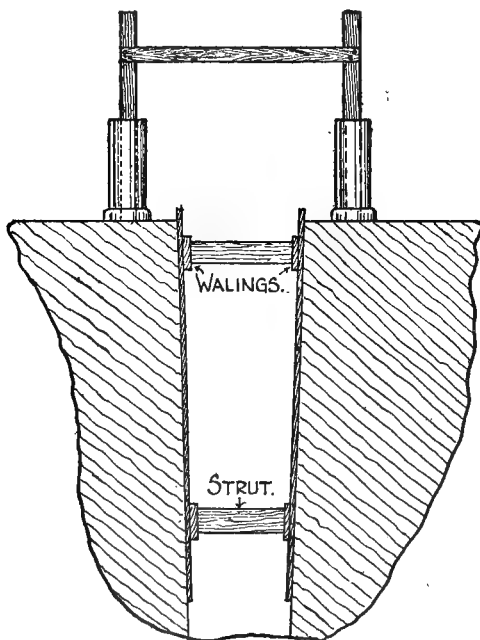


FIG. 159.—Method of fixing sight rails.

given in Fig. 160, where S denotes the iron stirrup, which is of sufficient length to pass the faucet and to rest on the invert of the pipe, whilst T shows the iron bands and thumb-screws for regulating the length of the rod.

In Fig. 161 a length of drain is indicated which requires to be laid with a gradient of 1 in 56 between points A and B. The invert of the drain at B is 20 feet above an assumed datum line, which may be adopted for the system of which the length AB forms a part. The top of a peg at the road

surface is 29 feet above the datum line, and the invert of the drain at B is 9 feet below the top of the peg, or 20 feet above the datum line as shown.

At points A and B the posts of the sight rails are erected, and at the higher point the cross-rail may be fixed at any convenient height. The height of the cross-rail at the lower point is determined by the aid of an ordinary level, which is placed midway between the two sight rails in

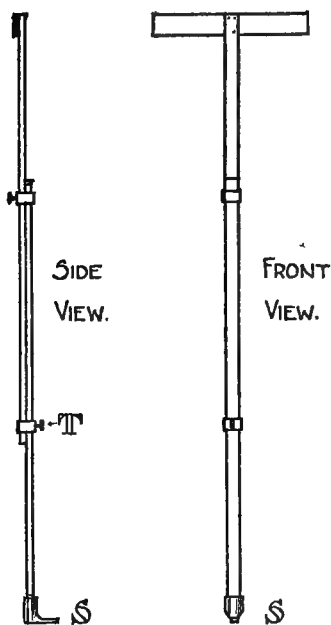


FIG. 160.—Adjustable boning rod.

order to eliminate errors of collimation. The length of drain under consideration is 196 feet, and with a gradient of 1 in 56 the difference in level between the two ends must be 3.5 feet. Assuming a levelling staff is held on the top of the cross-rail at B, and the reading is 3.12 feet, the staff when held on the top of the lower sight rail should read $3.12 + 3.5 = 6.62$ feet. To obtain the position of the latter, the staff may be held against one of the uprights and the height of the staff adjusted until the reading is 6.62, when a mark can be made on the upright at the bottom of the staff; to the latter point the cross-rail should be securely fixed, and an ordinary spirit level may be used for levelling the cross-rail. The

boning rod is then adjusted to the required length, which for the case given, taking the data at point A, would be $(26.26 - 16.5) + (10.01 - 6.62) = 13.15$ feet. As the invert of the drain must be parallel with the line of sight, the cross head of the boning rod should be exactly in line when fixed on the invert at any point, and when looking over the sight rails from one to the other.

When sight rails and boning rods are used for laying

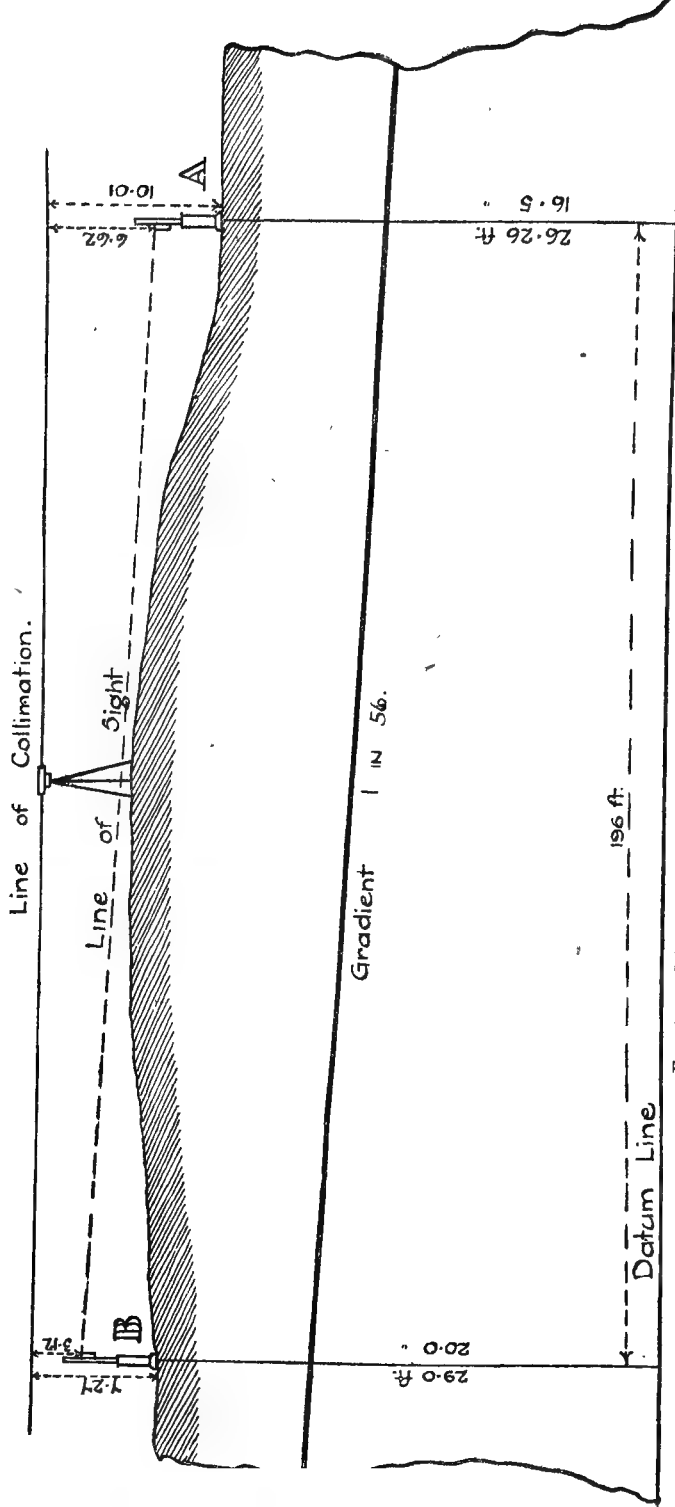


FIG. 161.—Diagram indicating method of obtaining positions for sight rails.

drains, every length of pipe or channel is laid with reference to the datum line.

Timbering Trenches.—It is essential when excavating, that the sides of drain trenches be properly supported to prevent their falling in. The manner of timbering trenches depends chiefly upon their depth, upon the nature of the earth, and upon the position in which the trenches require to be cut.

When cutting through stiff clays only a few timbers are required, even where the trenches are fairly deep, but for a loose earth timbers should be freely used, or the sides of the trenches are liable to fall in, especially in wet weather.

The timbers used are generally termed poling boards, walings, and struts. Poling boards are of any convenient length and width; they vary from 1 to 2 inches in thickness, and are vertically fixed against the earth to be supported. Walings are strong timbers, and are horizontally placed in front of the poling boards; these are of various widths and thickness, and are fixed near the tops and bottoms of the poling boards. Where poling boards are very long, walings are also placed at intermediate points.

Struts are cross-pieces which hold the timbers in position; in depth, struts should nearly equal the widths of the walings, and be from $1\frac{1}{2}$ inches and upwards in thickness.

In deep cuttings, struts should be fixed immediately over one another in order to allow room for excavating, and be placed at intervals of 6 to 8 feet apart.

Trenches should be cut tapering a little inwards, so that in case of a slip or subsidence the timbers would tend to wedge together, instead of falling from their respective places.

When quick or running sands are encountered, timbering requires to be specially well done to keep the sand out of the trench. For such cases grooved and tongued poling boards are necessary, and any open joint requires to be well caulked with tow or other suitable material.

It is also important that special attention be paid to timbering when a trench is cut near to and lower than the foundations of a building, or the stability of the latter may be endangered. Care must also be observed when removing timbers from cuttings of the latter class; the principal timbers

in such cases should be left in position when the earth is replaced, in order to avert any disturbance of the structure due to settlement of the newly replaced earth.

Drain Testing.—During the laying of drains it is desirable that some reliable test be applied from time to time as the work proceeds, and whilst the pipes are bare, as any defect is more readily located and more readily righted. A final test should also be applied at the completion of a scheme, both to test the general soundness of the drains and the resistance offered by the water seals of traps.

The general tests applied to drains are four in number, and are known as *hydraulic*, *air*, *smoke*, and *smell* tests. In the hydraulic test a drain is filled with water, after first firmly plugging up its lower end by means of a suitable plug or stopper. Water may be run into a drain from any convenient point, but the head upon a fireclay drain should not as a rule greatly exceed 7 feet, or water may show signs of oozing through the pores of the material. Stoneware pipes of good quality would stand a greater head without showing similar signs of leakage.

After a length of drain has been charged, the water level should be maintained for not less than 30 minutes. At first, however, even when earthenware drains are sound, the water level may slowly fall for a short time, on account of the material absorbing a certain volume of water. Where a number of branches occur in any particular section under test, a few gully traps may require to be plugged in order that the necessary head of water may be obtained.

Test junctions are very useful in drains, as a system may be divided into comparatively small sections for testing purposes.

For testing the soundness of the materials which enter into the construction of drains, the hydraulic test is a reliable one, but it is incomplete by itself, as it fails to indicate whether a trap has a water seal or not.

It is sometimes contended that the hydraulic test is too severe for earthenware drains, and that it subjects them to varying degrees of strain on account of its varying head. If, however, the actual pressure which is necessary to burst an

earthenware pipe is compared with that due to 7-feet head of water, it is very difficult to see where the severity of the hydraulic test comes in; further, as any drain is liable to be choked by foreign matter getting into it, the damming up of the water may subject a drain to a similar test. The argument against the hydraulic test that unequal strain (which is the result of varying internal pressures) has an ill effect upon a drain is absurd, especially when the maximum strain is so comparatively small. Unequal strains, however, which really have a destructive effect upon earthenware pipes are those due to external forces, which are principally caused by unequal settlement of the ground.

Air Tests.—To apply the air tests to drains, all that is necessary is to stop up all open ends, and to force in air at any point by means of a pump or bellows; the air pressure may be recorded on a simple form of water gauge, or upon a spring coil gauge, the type of gauge depending upon the extent of the pressure desired.

Where traps are connected with a system to be tested, the air pressure is usually controlled by the water seals of the traps, and generally not more than 1 inch of water pressure can be applied. Where traps are absent or plugged, any desired safe pressure may be applied, but as a rule it is not necessary to exceed a pressure of 3 lb. per sq. inch on account of the searching nature of this test.

So far as testing is concerned, both for ascertaining the soundness of a system and the resistance offered by the seal of a trap, the air test is a very good one, and one that is easily applied. Instead of using a spring coil gauge for recording higher pressures, the ordinary water gauge will suffice if mercury is substituted for water. If a system is faulty it is readily indicated by the gauge.

The chief difficulty which is associated with the air test is in the discovery of a leakage when one exists, and the smaller the defect the more troublesome it is to find. This drawback, however, may be overcome to a great extent by first dividing a system into a number of parts, and ascertaining the section in which the defect exists. Smoke may afterwards be forced through the section to aid in locating the defective point.

An air test is far more searching than a hydraulic one, although the former may be applied at a much lower pressure, as air will pass through small interstices, where water would simply clog them up.

Smoke Test.—This test is widely adopted, but it is often applied in a very perfunctory manner. There are two methods of smoke testing, viz.: by the use of smoke rockets, and by forcing smoke into drains or other pipes with the aid of a machine.

The smoke test is carried out by introducing smoke at the lowest end of a system of pipes, and when all air is dislodged, the outlets at the higher levels are then plugged. For a final test the smoke test is not one of the best; the condition of a drain with regard to its dryness or wetness very materially affects the test, and if no smoke is found to issue at any point from a drain, that may be no guarantee that such a drain is free from defects.

When smoke testing is adopted for drains that are buried in the ground, the latter is sometimes pierced with a long steel spear in the immediate neighbourhood of the drains, so as to provide a means of escape for smoke if a defect exists.

Smoke rockets are not suitable for final tests on account of the limited volume of smoke they produce, and neither can any pressure be generated with rockets. For a preliminary test smoke rockets are sometimes useful, and they may also be of service in locating a leakage when one is known to exist.

Smell Test.—The modern method of applying a smell test is to flush through the trap of a w.c. or through a gully a sealed tube which contains some strong smelling compound; the tube or "grenade," as it is often termed, takes different forms, but all are arranged that their contents may be discharged into drains, and the odour detected by the sense of smell if a defect exists. A smell test may sometimes be used as a preliminary one, but as it is not a positive test it is unsuited for final testing.

Remarks.—Generally speaking, the most suitable form of testing for iron drains is by the use of air; earthenware drains are better tested with both the hydraulic and smoke tests, as these will seldom withstand an air test. The best

results can be obtained by smoke testing when no water is flowing through a drain, and when its inner surfaces are dry. For testing pipes above ground level, such as waste and soil pipes, either the air or smoke test may be used, but the former is the better of the two.

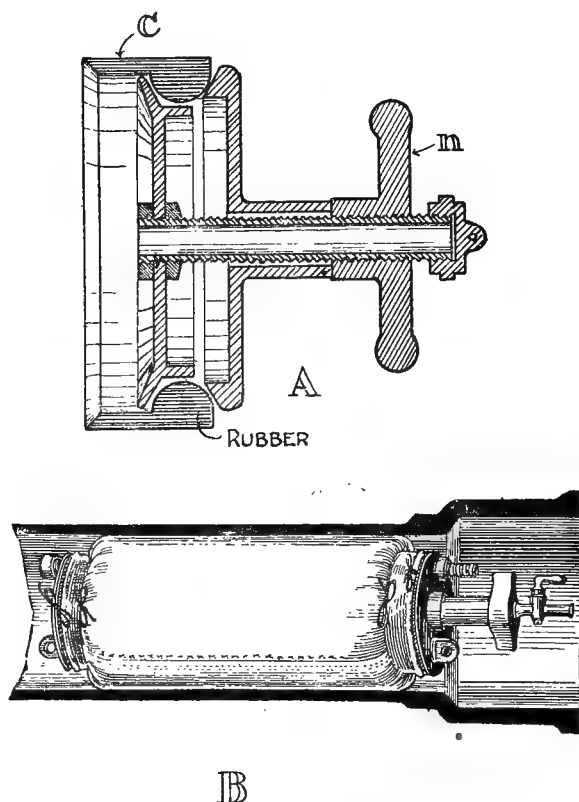


FIG. 162.—At A the “Addison” stopper is shown, and B gives a bag stopper by Nicholls and Clarke.

Testing Appliances.—For stopping either the inlets or outlets of drains and of other pipes, expanding plugs and rubber or canvas bags are used. At A, Fig. 162, the “Addison” stopper is shown, where a rubber ring is expanded between two galvanized iron discs by means of the wing nut *n*; this

stopper is formed at C on the cup leather principle, so that internal pressure may aid in making a tight joint. The central tube on which the wing-nut is screwed serves as a means for the escape of water prior to the removal of the stopper, when the hydraulic test is applied; it also admits of a connection being made with a smoke machine for testing purposes.

There are various forms of expanding stoppers, and although similar in principle they differ a little in minor details.

A bag stopper B, Fig. 162, is made both in cylindrical and

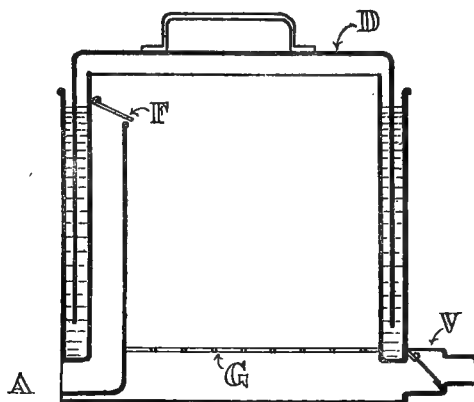


FIG. 163.—Smoke producing machine.

globular forms, but the latter is not so good as the one shown, owing to its having a much smaller bearing surface. Bag stoppers are inflated after being placed in position by means of an air-pump, and they are provided with stop-cocks to retain the air in them.

The chief advantage of bag stoppers is their lightness, and one stopper may be used for testing pipes from 4 to 9 inches diameter.

Smoke testing machines take various forms, a simple type being given in Fig. 163. The sides of the machine are water jacketed, and along with the cover or dome D form a seal to prevent the escape of smoke when a drain is being

tested. When the cover is raised air flows through the inlet A to fill the space, a non-return valve V being arranged to prevent smoke returning from the drain. From the machine a

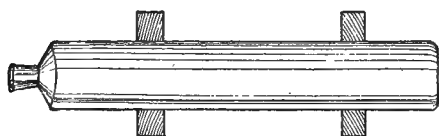
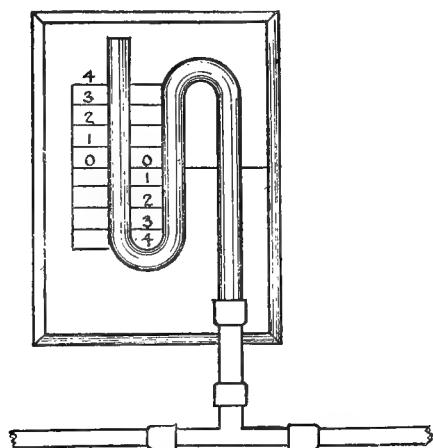


FIG. 164.—Smoke rocket.

of the machine any suitable smoke-producing material, such as brown paper, rag, or cotton waste, and which has first been steeped in creosote oil, may be used. To prevent water flowing



AIR PUMP.

FIG. 165.—Gauge and air pump.

into the machine when the latter is in use, the outer casing should be lower than the inner lining, as in Fig. 163. A flexible tube is used to connect the machine with the drain or pipe to be tested, the soundness of the latter being indicated by the movable cover D, which will be held up by the internal pressure or fall as the case may be.

In Fig. 164, a smoke rocket is shown with two pieces of lath attached to keep it above the invert of a drain. Rockets when lighted produce dense volumes of smoke, and two or more may be used at one time.

A gauge in its simplest form for air testing is given in Fig. 165, and it may be placed in any convenient position

when joined with the air delivery tube from the pump. To read the pressure on the gauge, a graduated piece of stiff white paper or thin cardboard may be used and fixed to a suitable frame, or the latter may be prepared and graduated instead.

Fig. 166 gives Banner's grenade, which is made of thin glass, and filled with a strong-smelling chemical substance.



FIG. 166.—Banner's grenade.

These grenades are only about 2 inches long, so that a few may readily be carried in a waistcoat pocket. To float a grenade through a trap, the former may be fixed to a hard wooden ball of about $2\frac{1}{2}$ inches diameter as in Fig. 167; this is known as Banner's "Explorer," and to it is attached a length of cord to enable it to be withdrawn from the drain. When the ball has been carried to the desired point, the grenade is broken by the aid of a spring upon giving the cord a sudden jerk.

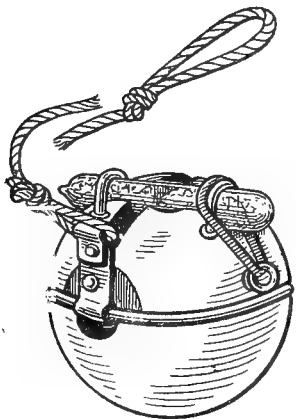


FIG. 167.—Banner's explorer.

Other forms of chemical testers are used, but they chiefly differ from the above in the manner their contents are discharged.

Discharging Capacity of Drains.

—Although much progress has been made in the design of drainage schemes, drains are still often laid that are far too large for their purpose. Frequently it is found that 9-inch pipes are used where those of 5 or 6 inches diameter would be more suitable, and 6-inch drains where 4-inch pipes would suffice.

Where practicable, drains should be laid with gradients which will give the discharging matter a minimum velocity of 3 feet per second, in order that they may be self-cleansing. The conditions upon which the velocity of discharge chiefly depends are: gradients of drains, size of drains, number and

kind of bends used, depths of flowing liquid, and the initial velocity of the entering water.

The effect of the gradient upon the velocity of flow is proportional to the square root of the sine of the gradient, this value being obtained by dividing the vertical fall by the

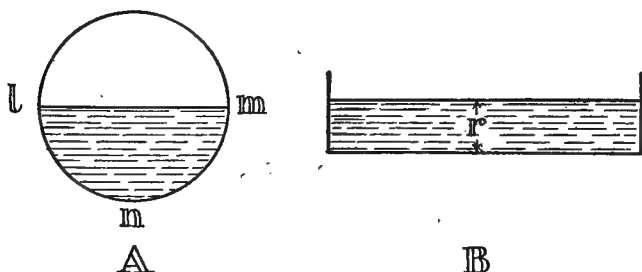


FIG. 168.—Diagram illustrating hydraulic mean depth.

length of the drain under consideration. Thus, if a length of drain is 75 feet, and has a vertical drop between the two ends of 1 ft. 6 in., the sine of the gradient = $\frac{1.5}{75} = .02$.

Size of drain and depth of water influence what is termed the *hydraulic mean depth*, and the velocity of flow is proportional also to the square root of this value.

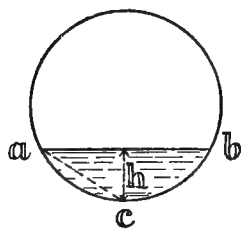


FIG. 169.

Hydraulic Mean Depth.—At A, Fig. 168, a pipe is represented as flowing half full. If we assume that the semicircular section *lmn* could be cut or bent so as to form a rectangular channel B, Fig. 168, whose width is equal to the wetted surface *lmn*, then instead of having varying depths from the water surface we should have a uniform depth *r* as shown at B. The

depth *r* is the hydraulic mean depth required, and this is obtained by dividing the sectional area of the flow by the length of the wetted arc. When a drain, however, is flowing full, or half full, its hydraulic mean depth may be found by simply dividing its diameter in feet by 4.

To obtain the hydraulic mean depth when drains are

flowing other than full or half full, and when a student has no knowledge of trigonometry, the following method may be used. Let Fig. 169 represent a drain flowing less than half full. Now, before the area abc can be found the length of the chord ab must be ascertained, either by measurement from a drawing or by calculation.

The following formula may be used for calculating the length of chord ab , when the depth of flow and the diameter of the drain are known :—

$$\text{Chord } ab = 2\sqrt{h \times (D - h)} \quad . \quad . \quad . \quad . \quad (1)$$

Where h = depth of flow in feet.

„ D = diameter of drain in feet.

The area of segment abc , Fig. 169,

$$= \left\{ \left(\frac{2 \times ab \times h}{3} \right) + \frac{h^3}{2 \times ab} \right\} \quad . \quad . \quad . \quad . \quad (2)$$

and the wetted surface acb , Fig. 169,

$$= .01745 \times \theta \times R. \quad . \quad . \quad . \quad . \quad (3)$$

Where θ = number of degrees in segment

„ R = radius of circle

The number of degrees in segment may be obtained by the aid of a protractor after drawing the pipe full size or to a large scale.

Another method of obtaining the wetted perimeter or surface acb , Fig. 169, is by the following rule :—

$$\text{Length of arc } acb = \frac{8ac - ab}{3} \quad . \quad . \quad . \quad . \quad (4)$$

and the length of a straight line ac

$$= \sqrt{\left(\frac{1}{2} ab\right)^2 + h^2} \quad . \quad . \quad . \quad . \quad (5)$$

If the depth of flow exceeds half the diameter of a drain, its area may be obtained by finding the area of the upper segmental part and deducting it from the area of the whole circle.

In like manner, the wetted perimeter may be determined when a drain is flowing more than half full by first obtaining the length of the unwetted arc, and deducting it from the circumference of the pipe which is being considered.

Example 1.—Determine the hydraulic mean depth of a 6-inch pipe when the depth of the water flowing is equal to one-quarter of the diameter, as in Fig. 169.

Before the sectional area of abc can be found the length of the chord ab must first be known. The depth of the flow h when a 6-inch drain is running one-quarter full = .125 feet.

By Formula 1, $ab = 2\sqrt{h \times (D - h)}$.

Substituting values, $ab = 2\sqrt{.125 \times (.5 - .125)}$,

$$ab = 2\sqrt{.046875};$$

$$\therefore ab = \underline{.433 \text{ feet.}}$$

From Formula 2 the sectional area of abc

$$= \frac{2 \times ab \times h}{3} + \frac{h^3}{2 \times ab},$$

$$\text{and when values are substituted} = \frac{2 \times .433 \times .125}{3} + \frac{.125^3}{2 \times .433}$$

$$= .0361 + .0023;$$

$$\therefore \text{sectional area } abc = \underline{.0384 \text{ sq. feet.}}$$

The length of the wetted perimeter may be found by Formula 4, but before this rule can be applied the straight line ac , Fig. 169, must first be known.

By Formula 5, $ac = \sqrt{(\frac{1}{2}ab)^2 + h^2}$.

Substituting values, $ac = \sqrt{(\frac{1}{2} \times .433)^2 + .125^2}$,

$$ac = \sqrt{.0625};$$

$$\therefore \text{length, } ac = \underline{.25 \text{ feet.}}$$

Formula 4 may now be applied, where

$$acb = \frac{8ac - ab}{3}.$$

$$\text{Substituting values, } acb = \frac{(8 \times .25) - .433}{3} = \frac{1.567}{3}$$

$$\therefore \text{wetted surface } acb = \underline{.522 \text{ feet.}}$$

As the hydraulic mean depth r is found by dividing the area of flow by the wetted surface,

$$\text{then } r = \frac{.0384}{.522} = \underline{.0735 \text{ feet.}}$$

To facilitate calculations being made in connection with drainage work, the following table is given :—

TABLE III.

DATA FOR OBTAINING HYDRAULIC MEAN DEPTH, AND THE SECTIONAL AREA OF FLOW IN CIRCULAR DRAIN PIPES, WITH WATER FLOWING AT DIFFERENT DEPTHS.

Depth of flow in terms of diameter.	Hydraulic mean depth ".	Cross sectional area of flow.
Full	$D \times \cdot 25$	$D^2 \times \cdot 7854$
$\frac{3}{4}$ "	$D \times \cdot 296$	$D^2 \times \cdot 632$
$\frac{2}{3}$ "	$D \times \cdot 292$	$D^2 \times \cdot 556$
$\frac{1}{2}$ "	$D \times \cdot 25$	$D^2 \times \cdot 393$
$\frac{1}{3}$ "	$D \times \cdot 186$	$D^2 \times \cdot 229$
$\frac{1}{4}$ "	$D \times \cdot 147$	$D^2 \times \cdot 154$

D=diameter of drain in feet.

Bends and changes of direction retard the velocity of flow to a great extent, and the quicker a bend the greater the resistance offered. When open channel bends are used which permit of a discharge splashing over them, the velocity will be further retarded by them.

Smoothness or roughness of a surface also has its effect, and it is fairly obvious that the smoother a pipe surface is, other conditions being equal, the smaller the frictional resistance will be.

Formulae for obtaining the velocity of discharge through drains are very numerous, but one of the best is that by Kutter.

Where $v = c \sqrt{r \times s}$ (6)

„ v = velocity in feet per second.

„ r = hydraulic mean depth in feet.

„ s = sine of inclination = fall \div length.

„ c = a coefficient which varies with the size and condition of a pipe.

For smooth drain pipes

$$c = \frac{181 + \frac{.00281}{s}}{1 + \left[\left(41.6 + \frac{.00281}{s} \right) \times \frac{.013}{\sqrt{r}} \right]}$$

For general work the values of c take too long to work out by the formula given, but by the aid of Table IV., which gives values of c for varying depths of flow, the general formula is rendered convenient.

TABLE IV.

Diameter of drain in inches.	Values of c (calculated by the writer).			
	Depth of flow in drain.			
	Full.	$\frac{3}{4}$ full.	$\frac{1}{2}$ full.	$\frac{1}{4}$ full.
4	66	68	66	54
5	68	72	68	57
6	71	75	71	60
7	74	78	74	63
8	77	81	77	66
9	80	84	80	69

It will be observed, upon reference to Table IV., that the values of c increase with the diameter of a pipe, and are highest when a drain is flowing three-quarters full and lowest when running only one-quarter full. It is therefore of importance when deciding upon a suitable gradient that attention be paid to the probable normal depth of flow.

Example 2.—Find the gradients which will give a velocity of 3 feet per second in a 6-inch drain when flowing $\frac{1}{4}$ and $\frac{1}{2}$ full respectively.

By transposing Formula 6 and substituting $\frac{h}{l}$ for s we have

$$l = \frac{c^2 \times r \times h}{v^2} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

Where l = length of drain in feet.

" h = vertical fall in feet for the given length.

c , r and v as before.

Upon reference to Table III. the hydraulic mean depth $r = .25 \times D = .25 \times .5$ when a 6-inch drain is running $\frac{1}{2}$ full, and $.147 \times D = .147 \times .5$ when flowing $\frac{1}{4}$ full. The values of c from Table IV. for the same depths of flow in a 6-inch drain are 71 and 60 respectively.

When a 6-inch drain is flowing $\frac{1}{4}$ full the length of drain per foot of fall to give a velocity of 3 feet per second is found by Formula 7.

$$\text{Where } l = \frac{c^2 \times r \times h}{v^2}.$$

$$\text{Substituting values, } l = \frac{60^2 \times .5 \times .147 \times 1}{3^2},$$

$$l = \frac{3600 \times .5 \times .147}{9};$$

$$\therefore l = \underline{29.4, \text{ or say } 30.}$$

And the gradient necessary for a 6-inch drain to give a velocity of 3 feet per second when flowing only $\frac{1}{4}$ full = 1 in 30.

When flowing $\frac{1}{2}$ full

$$l = \frac{c^2 \times r \times h}{v^2}.$$

$$\text{Substituting values, } l = \frac{71^2 \times .5 \times .25 \times 1}{3^2},$$

$$l = \frac{5041 \times .5 \times .25}{9};$$

$$\therefore l = \underline{70.}$$

For this case the necessary gradient will be 1 in 70.

The calculations serve to show to what extent the depth of flow has upon the velocity in the same pipe, and a comparatively quick gradient is necessary when a 6-inch drain only flows one-quarter full. For short drains where a discharge enters with a high velocity, rather flatter gradients could be used, but for long drains the formula given is a safe one to use.

When the velocity of flow has been determined, the discharging capacity of a drain in gallons may be ascertained by multiplying the cross sectional area of flow by the velocity, and afterwards by $6\frac{1}{4}$. Expressed as a formula—

$$G = A \times v \times 6\frac{1}{2} \quad (8)$$

Where G=gallons discharged per second.

„ A=sectional area of flow in feet.

" v = velocity in feet per second.

„ $6\frac{1}{4}$ = volume in gallons equivalent to one cubic foot of water.

Example 3.—Find the discharge in gallons per minute of a 6-inch drain when flowing $\frac{3}{4}$ full and when laid with a gradient of 1 in 50.

By Formula 6, $v = c \sqrt{r \times s}$.

The value of $s = 1 \div 50 = .02$.

From Table IV. the value of c will be found to be 75, and from Table III. $r = D \times .296$.

Substituting values, we have

$$v = 75 \times \sqrt{.5 \times .296 \times .02}.$$

$$v = 75 \times .054;$$

$\therefore v = 4.05$, ft. per second.

The discharging capacity of the drain may now be found by Formula 8,

where $G = A \times v \times 6\frac{1}{4}$.

In Table III. the sectional area of flow when a drain is $\frac{3}{4}$ full = $D^2 \times .632$, and for a 6-inch drain = $.5^2 \times .632$.

Substituting values $G = .5^2 \times .632 \times 4.05 \times 6\frac{1}{2}$;

$\therefore G = 3.999$, say 4 gallons per second,

and the discharge per minute $= 4 \times 60 = 240$ gallons.

For general work the gradients given in the following table are suitable for short lengths of drains.

TABLE V.

DIAMETER DRAIN.		GRADIENTS.	
4 inch branch from yard gully .	.	1 in 24=1	inch in 2 ft.
4 inch main drains . . .	.	1 in 36=1	„ in 3 ft.
5 „ „ „ . . .	.	1 in 42=1	„ in 3 ft. 6 in.
6 „ „ „ . . .	.	1 in 48=1	„ in 4 ft.
7 „ „ „ . . .	.	1 in 60=1	„ in 5 ft.
8 „ „ „ . . .	.	1 in 78=1	„ in 6 ft. 6 in.
9 „ „ „ . . .	.	1 in 102=1	„ in 8 ft. 6 in.

CHAPTER IX

DISPOSAL AND TREATMENT OF SEWAGE FROM MANSIONS AND HOUSES IN COUNTRY DISTRICTS

IN rural districts it is often necessary, on account of the absence of a general sewerage system, to make special provision for the treatment and disposal of the sewage from large isolated buildings, or from a group of small dwellings.

Different methods of dealing with sewage can be adopted, but the choice of a system largely depends upon local conditions and the amount of money the owner of a property is prepared to spend.

The following methods of sewage disposal and treatment are in general use for small or private works.

1. Cesspools which overflow on to land or into some available stream.

2. Bacterial systems of purification.

- (a) Absorption and utilisation of sewage by means of sub-irrigation, and with or without preliminary treatment.
- (b) Treatment in septic tanks, and subsequent treatment of the effluent on land.
- (c) Treatment in septic tanks, and the subsequent passage of the effluent through contact beds or through filters.

The first method is usually a very unsatisfactory one, on account of the nuisance caused when emptying cesspools, the frequent pollution of the soil and underground water supplies by defective construction, and the pollution of streams by overflowing sewage.

Cesspools always possess objectionable features, even when soundly constructed. If they overflow on to land a rank

grass quickly grows on the area dosed, and their emptying is frequently delayed on account of the objectionable nature of the operation.

When cesspools are used they should be well ventilated and of water-tight construction; their size depends upon the daily amount of sewage they are likely to receive, whether rain-water is admitted into them or not, and the length of the interval before being emptied.

Generally speaking, the greater volume of the rain-water should be excluded from foul-water drains which either discharge into a cesspool, or into a tank in connection with a bacterial system of sewage treatment.

In a bacterial system, the purification of the sewage is accomplished by minute living organisms, which, when given suitable conditions, thrive, and carry out their work. The two chief classes of bacteria which are responsible for the purification of sewage are aerobic and anaerobic; the former require a liberal supply of oxygen for their development, whilst the latter only thrive in the absence of oxygen.

For a small scheme of sewage purification to be a success, it must be of simple construction and automatic in action: for if frequent attention is necessary the chances are that a system will be neglected, and sooner or later it will result in failure.

The simplest and most effective way of rendering sewage innoxious, and to purify it, is by passing it on to land which is of a good loamy nature. In the upper layers of earth bacteria are present in considerable numbers, and these attack the sewage, break it up into simple and harmless constituents, and in a form that may readily be assimilated by plant life. On account of the numerous bacteria which are present in the upper earth, the latter has been termed the "living earth," and nearly all the purification effected by a soil is done within the upper three feet; below this depth little purification is effected by a soil, and a depth is soon reached where organisms do not appear to exist.

System of Sub-Irrigation.—Under favourable conditions a system of drains may be arranged so as to distribute sewage that it can be absorbed by a given area of land. The drains,

however, should be kept as near to the surface as practicable, and the sewage requires to be discharged

so that every part of the prepared area receives its quota of sewage. In order to effect uniform distribution of sewage, a given volume must be discharged at one time; this method prevents the overdosing of isolated parts of an area, and allows the bacteria to better perform their work.

A simple sub-irrigation scheme of sewage treatment is given in Fig. 170. It consists principally of a septic tank S, a dosing chamber T, and a number of open-jointed field drains which are placed a certain distance apart on one or both sides of a main distributing pipe. The purpose of the septic tank is to liquefy as far as possible the organic solids in the sewage, in order that the latter will be in a better condition for percolating into the earth. The septic tank is shown provided

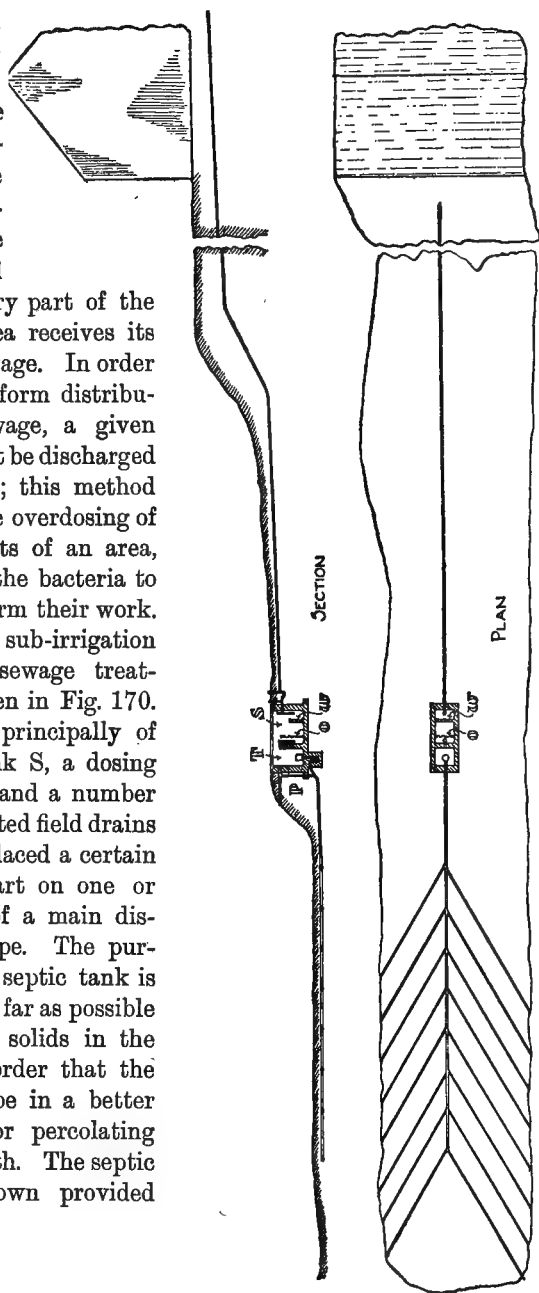


FIG. 170.—Subsoil irrigation scheme for purifying sewage.

with submerged inlet and outlet, and a wall W should be constructed near the inlet of the tank to prevent its contents being unnecessarily disturbed by a sudden inrush of water. In a small septic tank a screen may be also arranged at the outgo O, to prevent undigested solid matter passing into the dosing tank T.

When sewage is first turned into a septic tank, a certain time must elapse (largely depending upon weather conditions) before the tank properly performs its work; in other words, before septic conditions arise. A septic tank when once in working order should not be emptied, but provision should be made for removing any irreducible matter which may accumulate in it.

In the tank T a plenum automatic siphon is shown for discharging its contents into the subsoil drains; any other suitable contrivance may be used for the purpose, but anything that depends upon movable parts is usually more liable to get out of order. To the outgo of the siphon a pipe P is joined, which serves the purpose of an overflow for the tank and also as a ventilation pipe for the field drains.

The subsoil drains require to be carefully arranged, and a good porous soil is essential if the system is to be a success. The main subsoil drain, which may be of ordinary 4-inch pipes, should be laid level and not deeper than 1 foot below the surface of the ground; branches should be arranged as in plan. Fig. 170, that each may receive its proper volume of sewage. The open jointed branch drains should also be fixed level, and a suitable length per person is from 40 to 45 feet. The distance between the distributing branches should be regulated by the character of the soil, and will vary from $2\frac{1}{2}$ to 5 feet.

With regard to the sizes of the septic and dosing tanks, the former should have a capacity of about one day's flow and the latter about half a day's flow of sewage. To a great extent the capacity of the dosing chamber should be governed by the capacity of the subsoil drains. From dwelling-houses where modern sanitary conveniences are in use the volume of sewage discharged will be from 15 to 25 gallons per occupant per day. By making the dosing tank fairly large, the subsoil

drains will be the better charged, and in consequence the sewage will be better distributed.

Both the septic and the dosing tank should be covered, as the heat in the sewage is better maintained in cold weather, and covered tanks may be placed in positions where open ones would be objectionable.

Should it be found desirable to locate the septic tank, Fig. 170, in the immediate neighbourhood of a building, it may be advisable to dispense with the disconnecting trap on the drain, and to ventilate the tank by means of a soil or other ventilating pipe. A layer of earth should also be placed upon the roof of the tank, in order that any escaping gases may be deodorised in passing through it.

In certain cases a system of subsoil irrigation may be inapplicable, and it may be necessary to adopt artificial filters for the final treatment of the tank effluent.

Sewage filters are of two types, one being termed contact beds and the other percolating filters; the filtering medium, however, is the same in each type, and commonly consists of clinker, coke, or other material which provides suitable surfaces for the growth of bacteria. These filters operate by intercepting the larger particles of suspended matter in the sewage, and by oxidising the organic solids by the action of living organisms; if the process is carried far enough a clear and non-putrefactive effluent is obtained.

Contact beds in construction differ from percolating filters; the walls of the former require to be water-tight, and the filtering medium varies in depth from 2 ft. 6 in. to over 4 feet, according to the fall available. The walls of percolating filters may be cheaply formed, as water-tight construction is not essential, and they may also be perforated to aid the aeration of the filtering medium. Percolating filters are not usually less than 5 feet deep, and an increased depth produces an effluent of greater purity.

In either form of bacterial filter the bottom requires to be arranged that it can be effectively drained, the effluent being conducted to a suitable outlet. For the construction of a filter perforated tiles or pipes may be used for the under-drains, and upon these a layer of rough material should be

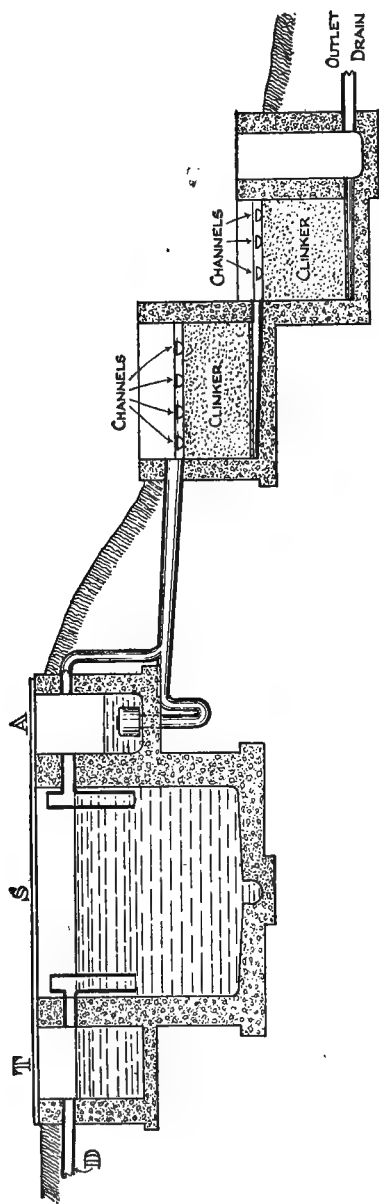


FIG. 171.—Small scheme for the purification of sewage.

placed; the body of the filter may be composed of material which is of a fairly uniform size, say from $\frac{1}{8}$ inch to $\frac{1}{4}$ inch, with all dust screened out.

When contact beds are used, the sewage after passing through the septic tank is distributed over the surface of a bed, and when the latter is full the sewage is allowed to remain in contact with the material for a period of about two hours, whilst the bacteria effect a certain amount of purification. After the contact period the effluent is discharged, and the bed remains empty for any period from say 4 to about 8 hours, in order that it may be thoroughly aerated.

With *percolating filters* the sewage is not retained as in contact beds, but after being evenly distributed over the surface of the filter the sewage trickles down and through the mass of material, and freely escapes at the outlet.

The volume of sewage with which a contact bed is capable of dealing

varies from 15 to about 20 gallons per sq. foot per day, according to the strength of the sewage.

With percolating filters their rate of working depends largely upon their depth, and the character of the sewage; the volume of sewage filtered varies from 18 to 36 gallons per sq. foot per day. When either a contact bed or a percolating filter yields an effluent of insufficient purity, further purification by secondary beds may be adopted.

Where adequate fall is available, a small purification works similar to Fig. 171 may be constructed, which consist of a detritus tank T, septic tank S, automatic dosing tank A, and primary and secondary filters. The house drain D is shown discharging into the detritus tank, which intercepts any mineral matter that may pass from a yard or other surface into the drain. From the detritus tank the sewage flows into the septic tank, where anaerobic organisms attack and break up the solid organic matter. The effluent from the septic tank flows into the automatic dosing tank A, which regulates the discharge and enables every part of the primary filter to be properly dosed with sewage; the interval between the periods of discharge also allows the filter to receive the necessary supply of oxygen for the development of the aerobic organisms. From a single house the discharge of sewage only takes place at irregular intervals, and unless some method is adopted for regulating the discharge the filters would not act satisfactorily, as some parts would be overdosed whilst other parts would have little or no work to do.

To distribute the tank effluent over the surface of a filter various methods may be adopted, but in Fig. 171 channels are shown which are supposed to be notched at short distances along each edge. Fixed jets or revolving sprinklers may, under favourable circumstances, be used for distributing the tank effluent, but the small orifices of jets are subject to chokage, and revolving sprinklers are usually too costly for a small system of sewage purification. After the effluent has percolated through the primary filter, it passes to the secondary filter, and thence to the outlet drain. The area of a secondary filter may only require to be half that of the primary filter, and the capacity of a septic tank for the installation shown

should be about equal to one and a half day's discharge. The automatic dosing tank for regulating the discharge may have a capacity of twenty gallons and over, depending upon the size of the purification works. It is not essential that a system should be so compact as that in Fig. 171, and the different units may be some distance apart if the fall of the ground should favour that arrangement.

CHAPTER X

WATER SUPPLY

IN nature there is no water which is absolutely pure, as it readily absorbs gases, and dissolves traces of many substances with which it comes in contact. The term "pure" is only used in a relative sense, and in general pure water is understood to be water which contains nothing which is likely to have any prejudicial effect upon those who consume it.

It is only in country districts where the average student of Sanitary Engineering is directly concerned with water at its source of supply, for in urban districts, where a scheme of water-supply has been carried out, water is delivered by a system of iron pipes, and is available in the various streets.

Water Pollution.—A point of importance is to deliver water to a dwelling without in any way impairing its quality and rendering it injurious to health.

Some of the ways in which water may be polluted are as follows:—

1. At its source, by coming in contact with decaying animal or vegetable matter.
2. Through badly constructed storage tanks or reservoirs, or by polluting matter being washed into them.
3. In a main distributing system.
4. By the materials of which service pipes are made.
5. Storage cisterns in houses.
6. Defective arrangement of service pipes.

Well waters may be contaminated by sewage or by polluted surface water gaining access to them, or where pumps are provided they may be the cause of the quality of the well water being impaired. Lead pumps and suction pipes are

frequently used in country districts, but where a water has any appreciable effect upon lead, iron pumps and pipes should be adopted. Surface water may be excluded from wells by having them properly covered, and by building the lining of the wells above the level of the surrounding ground. The lining of a well for the greater part of its depth should be of water-tight construction, in order that water may be unable to gain access without first having percolated through a large mass of earth. In the case of deep wells the subsoil water should be excluded altogether.

Where a supply of water is obtained from a spring, every precaution should be taken that the tank or reservoir in which the water is stored is suitably constructed, favourably located, and that the water channels are properly protected from possible pollution.

For a country house which is chiefly dependent upon the rainfall for its supply, the chief forms of pollution are due to the collecting surfaces, by the accumulation of vegetable growths, by droppings from birds (where pigeons and fowls are kept), and by metallic impurity. Tiled roofs are very susceptible to vegetable growths, and do not make such good collecting surfaces as slated roofs. Roofs which drain into lead gutters are not suitable for collecting areas where the water is to be used for dietetic purposes, as rain-water has a very active effect upon lead and dissolves traces of this metal.

With regard to the pollution of water by means of a distributing system, this may occur under favourable conditions where ball hydrants are in use. If, for example, polluting matter has gained access to a ball hydrant which is located at a high level, and the water is temporarily turned off, or is drawn from the higher level by an abnormal draught at a lower point, the hydrant may open and allow the polluting matter to enter and pass into the water pipes.

Coal-gas from a leaky main in the immediate neighbourhood of a ball hydrant may also enter a water main in a similar manner to the above, for when water is withdrawn from a main so as to partially empty the latter, air rushes in to take its place. Should coal-gas or other gas escape near

a hydrant, it may readily pass into a water main under the conditions stated.

Lead service pipes allow certain waters to dissolve traces of the metal, and this form of impurity when taken into the human system acts as a cumulative poison. When lead is dissolved by water, lead service pipes should not be used, that is if the water is used for human consumption in any form.

The following extract¹ clearly indicates the danger of the prolonged use of water containing traces of lead :—

“Acute lead poisoning, as manifested by lead colic, anæmia, paralysis, epilepsy, etc., is rarely met with as a result of the use of leaded waters, but the insidious forms of plumbism, or lead poisoning, which are much more common than the acute cases, are constantly with us. The effects produced by the small amounts of lead taken into the system are rarely so serious as to cause death, and for this reason the injurious results of the long-continued use of waters so polluted are only gradually receiving recognition.

“It is believed by those who are lucky enough to escape, that the risks of this kind of poisoning are exaggerated. The contrary is quite the case.

“The symptoms of chronic lead poisoning, such, for example, as are liable to ensue after the continuous use of water containing small quantities of lead, are as follows: The symptoms are usually slow in their progress; there is general anæmia, with a consequent anæmic pallor of the skin; there is often constipation and indigestion; there may be loss of appetite, an unquenchable thirst, a constant unpleasant, metallic taste in the mouth, and a foul odour of the breath.”

Waters which dissolve lead are usually those which contain little or no carbonate of lime. Waters which contain lime carbonates do not act upon lead, owing to a protective coating being formed on the surfaces of the metal. Soft waters as a general rule dissolve lead, but of these there are exceptions. For example, Loch Katrine water, which is used in Glasgow, is very soft, and although it has an appreciable effect upon new lead pipes, after a short time their inner surfaces become coated with a film of vegetable matter, which combines with

¹ *New Hampshire Sanitary Bulletin.*

the oxide of lead that is first formed and prevents further action taking place. The soft water from Thirlmere, which supplies Manchester, appears to have a similar effect on lead pipes as that from Loch Katrine.

In many districts storage cisterns require to be fixed in buildings where the pressure in the water mains falls too low to give a constant supply throughout the whole of a day, and unless such cisterns are formed of suitable material, are properly protected and suitably placed, contamination of the water will be the result. All storage cisterns should be provided with covers, so as to exclude foreign matter from them.

Pollution of a water supply by defective arrangement of service pipes is not very common at the present time, owing largely to the regulations imposed by water companies. In country districts where water is obtained from a private source irregular connections with service pipes may still be found; such, for example, as the direct connection of a service pipe with a urinal or a w.c., instead of the direct connection being broken by means of a flushing cistern.

Sources of Water Supply.—The principal sources of water supply for rural districts are Rain-water, Springs, and Wells; whilst Upland surface water and River water are frequently resorted to for supplying large communities. These, of course, all depend upon the rainfall for their replenishment.

Rain-water is the purest form of natural water when caught in country districts which are well removed from towns and industrial centres. Rain is naturally distilled water, being slowly evaporated from the sea and from water on the earth's surface; the aqueous vapour rises into higher regions to form clouds, and upon condensation again falls in the form of rain or snow.

In falling through the atmosphere rain-water absorbs any gases which may be present, and this accounts for the pollution of rain-water when caught in the neighbourhood of industrial centres, where the atmosphere is laden with impurities, such as particles of soot, sulphurous compounds, etc., and where it falls on surfaces which also intercept polluting matter.

Rain is rich in oxygen, and this has the effect of increasing its solvent powers. Fresh rain-water has a flat, insipid taste, but this may be improved by filtration.

For a house in a country district stored rain-water may occasionally be the principal or only convenient source of supply. When this is the case, and it is also used for drinking purposes, the following require special consideration :—

- (a) Suitability and sufficiency of collecting area.
- (b) Sufficient storage.
- (c) Suitable filtering arrangement.

Collecting Area.—The surface used for collecting rain-water requires to be kept as free as practicable from all polluting influences, and no rain-water should be used for dietetic purposes which flows through lead gutters. Slated roofs make good collecting surfaces, but where a suitable roof area is inadequate to yield the necessary volume of water, specially prepared surfaces are essential. When roofs are the collecting surfaces, the most suitable channels or receivers are cast-iron gutters which have their inner surfaces well coated with a bituminous paint such as Dr. Angus Smith's solution, or other leadless coating. The interior surfaces of cast-iron rain-water pipes should also be protected in a similar manner, whilst the external surfaces of either pipes or gutters may be protected with lead paint of any particular colour.

Earthenware drains are the most suitable channels for conducting rain-water to a storage tank from the rain-water pipes.

Special Collecting Areas take different forms. They may be raised above the contiguous ground and arranged to fall to one end, being rendered practically impervious with a covering of either cement or asphalt. At the lower end of a prepared surface a collecting channel may be arranged which discharges into a suitable sump so as to intercept leaves and similar matter. Collecting areas may also be arranged as in Fig. 172. In this case the rain falls upon a grass surface, percolates through say a foot of soil, and afterwards through perforated tiles which are placed upon an impervious floor. Special tiles may readily be obtained which will support the soil, and at the same time permit of

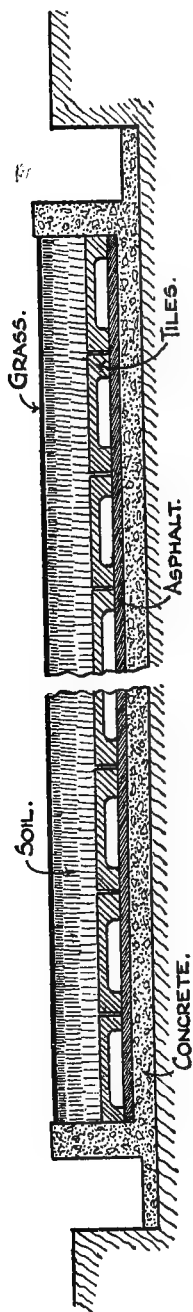


FIG. 172.—Earth filter for purifying rain-water.

adequate under drainage between the tiles and water-tight floor, which should be made to fall towards a sump at any suitable point. The collecting area in Fig. 172 takes advantage of the purifying effect of the organisms in the soil, as explained in the chapter on sewage treatment, and also of the purifying power of grass.

Where a collecting area requires to be excavated and prepared as in Fig. 172, it should be channelled all round, the bottom of the channels being lower than the floor of the prepared area; this provision reduces materially the chances of pollution.

All special collecting surfaces should be properly protected from surface pollution due to fowls, cattle, etc., by having them surrounded with a suitable fence. Stored rain-water is only suitable, of course, where the atmosphere is comparatively pure, as in most country districts.

Conditions affecting Yield by a Surface.

—The water yielded by a collecting area for storage purposes will depend upon the amount of rainfall, the nature of the area, and whether the whole or only a part of the available rainfall flows to the storage tank. Where rain falls directly upon an impervious surface nearly the whole of it may be passed to storage, but if the first part of the rain which washes the collecting surface is diverted to waste, then only a portion of the total rainfall is available for storage purposes. Showers of short duration may require deducting from the total rainfall where a separator is used, as the latter may not come into action.

When rain falls upon a surface like Fig. 172 a certain percentage is retained by the soil.

Rainfall.—The rainfall varies greatly in different parts of a country, and that of any locality principally depends upon the physical conditions of the surrounding districts, prevailing winds, and the distance from the sea.

“In the British Isles¹ the wettest districts include portions of the counties of Inverness and Argyll, the Lake District of England, and the mountainous parts of North Wales; the annual rainfall of these districts exceeds 80 inches. In some parts of the flat counties of Bedford, Cambridge, Norfolk, and Lincoln, the rainfall per annum is under 23 inches.”

“A large area of England, and all the more important agricultural districts in Scotland, have a rainfall under 30 inches, and the greater part of England and nearly the half of Scotland have a rainfall not exceeding 40 inches; in Ireland it is only in isolated parts where the rainfall is less than 40 inches.”

When the rainfall of any district is required, local records which have extended over a period of years should be obtained where possible.

So far as the rainfall of the British Isles in general is concerned, much information can be obtained from *British Rainfall*, by G. J. Symons.

Volume of Water Available.—The losses due to evaporation, absorption, and waste, etc., cannot readily be ascertained with exactness, and approximate values are used to a more or less extent.

The volume of rain-water available for storage purposes will roughly be as follows:—

- (a) From roofs and other impervious surfaces where a separator is used, 70 per cent.
- (b) From grass surfaces, as in Fig. 172, 65 per cent.
- (c) From roofs, and similar surfaces, where water flows direct to storage, 90 per cent.

To calculate the volume of water yielded by a surface, when its area and the rainfall are known, or to obtain the area

¹ *Encyclopædia Britannica*, 9th Edition.

of surface which will yield a given volume of water, the following formulæ may be used:—

Where G = gallons of water required.

„ A = area of collecting surface in sq. feet.

„ f = rainfall in inches.

For conditions represented by (a) $G = .37A \times f \dots (9)$

$$A = \frac{G}{.37 \times f} \dots (10)$$

For conditions represented by (b) $G = .34 \times A \times f \dots (11)$

$$A = \frac{G}{.34 \times f} \dots (12)$$

For conditions represented by (c) $G = .47 \times A \times f \dots (13)$

$$A = \frac{G}{.47 \times f} \dots (14)$$

Example 4.—If the rainfall of a certain district is 25 inches per annum, find the volume of water which is available for storage when the total collecting surface is 2400 sq. feet.

For condition (a) $G = .37 \times A \times f,$

$$G = .37 \times 2400 \times 25;$$

$$\therefore G = \underline{22,200 \text{ gallons.}}$$

For condition (b) $G = .34 \times A \times f,$

$$G = .34 \times 2400 \times 25;$$

$$\therefore G = \underline{20,400 \text{ gallons.}}$$

For condition (c) $G = .47 \times A \times f,$

$$G = .47 \times 2400 \times 25;$$

$$\therefore G = \underline{28,200 \text{ gallons.}}$$

Example 5.—What collecting area will be necessary where the rainfall is 28 inches in order to yield 54,750 gallons per year?

For condition (a) $A = \frac{G}{.37 \times f},$

$$A = \frac{54750}{.37 \times 28};$$

$$\therefore A = \underline{5285 \text{ sq. feet of surface.}}$$

$$\begin{aligned}\text{For condition (b) } A &= \frac{G}{.34 \times f}, \\ A &= \frac{54750}{.34 \times 28}; \\ \therefore A &= \underline{5751 \text{ sq. feet of surface.}}\end{aligned}$$

$$\begin{aligned}\text{For condition (c) } A &= \frac{G}{.47 \times f}, \\ A &= \frac{54750}{.47 \times 28}; \\ \therefore A &= \underline{4160 \text{ sq. feet of surface.}}\end{aligned}$$

Capacity of Storage Tanks.—It is obvious that the storage capacity of a rain-water tank need not be capable of accommodating the total rainfall, as the latter is distributed over the whole of a year. Under ordinary conditions, when entirely dependent upon the rainfall for a supply, the storage capacity in this country should be equal to about 80 to 120 days' supply, according to whether a district is a wet or a dry one. A less capacity will, of course, suffice where rain-water can be supplemented by water from another source.

Water Consumption.—The consumption of water is usually stated in gallons per head of a population, and this varies considerably in different localities. In towns the consumption per head varies from 20 to about 60 gallons per day, smaller towns, as a rule, consuming less per head than the larger ones. In rural districts the consumption per head varies from less than 9 to about 20 gallons per day, the smaller value applying when w.c.'s are not in use.

Size of Tanks.—For obtaining the size of a rectangular tank the following formulæ may be used:—

Let P = number of persons for which storage is provided.

„ C = gallons allowed per head per day.

„ S = number of days' storage.

„ l = length of tank in feet.

„ b = breadth of tank in feet.

„ h = depth of tank in feet.

$$l = \frac{P \times C \times S}{b \times h \times 64} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (15)$$

$$b = \frac{P \times C \times S}{l \times h \times 6\frac{1}{4}} \quad . \quad . \quad . \quad . \quad . \quad . \quad (16)$$

$$h = \frac{P \times C \times S}{l \times b \times 6\frac{1}{4}} \quad . \quad . \quad . \quad . \quad . \quad . \quad (17)$$

Example 6.—Determine the width of a storage tank which is 21 ft. 6 in. long, and 8 feet deep below the overflow, to hold 80 days' supply for 12 persons, where the rate of consumption is 15 gallons per head per day.

By Formula 16, $b = \frac{P \times C \times S}{l \times h \times 6\frac{1}{4}}.$

Substituting values, $b = \frac{12 \times 15 \times 80}{21\frac{1}{2} \times 8 \times 6\frac{1}{4}},$

$$b = \frac{2 \times 12 \times 15 \times 80 \times 4}{43 \times 8 \times 25};$$

$$\therefore b = 13\frac{7}{8} \text{ ft., say } \underline{13 \text{ ft. 5 in. broad.}}$$

Should a circular tank be constructed, the formula for calculating its diameter or depth may be expressed as shown below.

$$h = \frac{P \times C \times S}{D^2 \times 4\frac{9}{10}} \quad . \quad . \quad . \quad . \quad . \quad . \quad (18)$$

$$D = \sqrt{\frac{P \times C \times S}{h \times 4\frac{9}{10}}} \quad . \quad . \quad . \quad . \quad . \quad . \quad (19)$$

Where D=diameter in feet, and h , P , C and S as before.

Example 7.—If storage is provided for 20 persons for 60 days, what depth of tank will be essential, if its diameter is fixed at 20 feet, and the rate of consumption at 12 gallons per head per day?

Formula 18 gives $h = \frac{P \times C \times S}{D^2 \times 4\frac{9}{10}}.$

Substituting values, $h = \frac{20 \times 12 \times 60}{20^2 \times 4\frac{9}{10}};$

$$\therefore h = 7\frac{1}{4} \text{ ft., say } \underline{7 \text{ ft. 4 in. deep.}}$$

Example 8.—Assuming the depth of the tank had been fixed at 9 ft. 6 in. below the overflow, and the diameter of tank was required.

Then by Formula 19, $D = \sqrt{\frac{P \times C \times S}{h \times 4\frac{9}{10}}}$,

and substituting values, $D = \sqrt{\frac{20 \times 12 \times 60}{9\frac{1}{2} \times 4\frac{9}{10}}}$,

$$D = \sqrt{309.34};$$

$\therefore D = 17.58$ ft., say 17 ft. 7 in. diameter.

Purification of Rain - Water.—To render rain - water sufficiently pure for drinking purposes, and also to improve its taste, it requires to be filtered. On the other hand, if rain-water is only stored for general household use, and also to

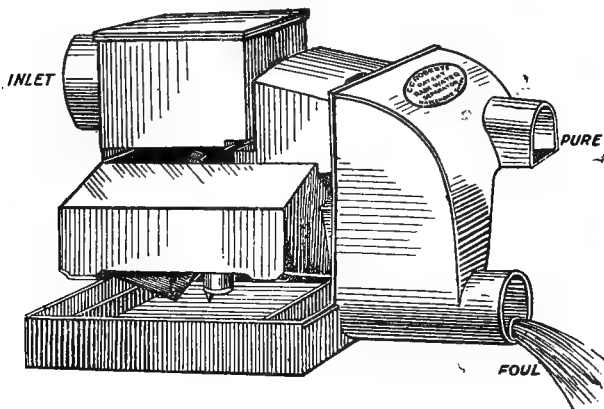


FIG. 173.—Roberts' rain-water separator.

supply sanitary fittings, a high degree of purity is not essential, and simple straining may be all that is required.

Rain-Water Separators.—A useful appliance for preventing the first portion of the rainfall from entering a storage tank is a rain-water separator, Fig. 173 (Roberts'), which can be fixed at any suitable point in a drain leading to the storage tank. The rain-water separator shown is self-acting, and simply diverts to waste the first portion of the rain which contains the greater portion of the impurities which have accumulated on the collecting area. Its action is dependent upon a canting or tipping compartment, which is regulated to fill at a given rate. When the canter is up or in its normal position, the rain-water flows through the lower or

foul-water outlet; but if the canter is full of water it tilts downwards and diverts the entering water through the upper outlet; the interval required for filling the canter is the time allowed for washing the collecting surface. The canter is emptied by means of a siphon, when it tilts back to

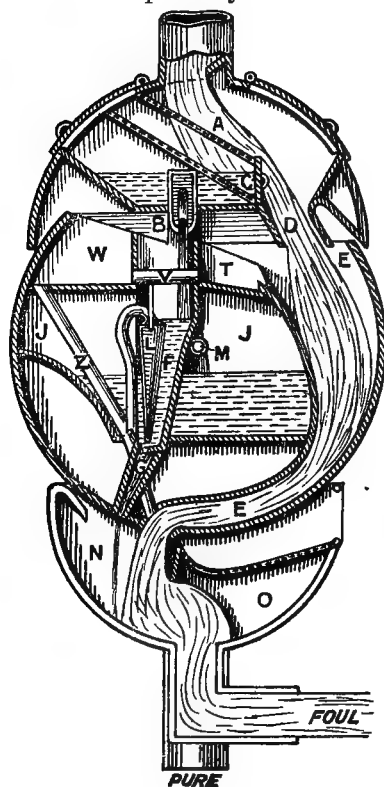


FIG. 174.—Roberts' rain-water separator.

its former position some time after the rain has continued to fall. If a shower of rain is only of short duration and light, the canter will not come into action, but the whole of this water will flow to waste. Separators are made in a number of sizes, to suit either small or large collecting areas, and for either town or country use.

Another form of Roberts' separator is shown by Fig. 174, for fixing in conjunction with a stack of pipes so as to deliver the rain-water either above or below ground level. The vertical type Fig. 174, which is shown in section, contains the following principal parts. Beginning at the top, A denotes movable strainers, and B a perforated slide which regulates the flow of water to the canter. The

small chamber at C contains a sluice which can be adjusted to suit the area of the collecting surface. E shows the course taken by the water when flowing through the separator, and J represents the canting chamber which turns for a limited distance on a pivot *m*. The small compartment F in the canter is provided with a small regulated outlet G, which discharges into the lower part of the separator. A siphon L has its

outlet leg in chamber F, whilst its inlet leg is turned into the large chamber J. The lower portion of the separator is divided into two parts, N and O, by a thin plate, in order that the canting chamber may divert the water on either side of this plate according to the relative position of the canter.

Its action is as follows: When water enters the separator, a portion of it passes through the strainers A, and into small upper chamber C, from which it flows through the perforated slide B to the small compartment F; when the latter is full, the water overflows into the main body of the canting chamber J, and after a time the canter turns and diverts the water into chamber O, from which it flows to storage. Prior to canting the water is delivered into chamber N, from which it is passed to waste as in Fig. 174. The small chamber F is slowly emptied by means of the small aperture G, and as the level of the water falls the siphon is brought into action, when the water from the canting chamber is also discharged.

To ensure these separators working properly they require periodical attention to keep the small apertures and strainers clear, and also to lubricate the pivot on which the canter turns.

When a more simple and cheaper appliance is required, a spout or channel might suffice, which can be tilted one way or the other, and so divert the water either to storage or to waste.

Sand Filters.—A well constructed sand filter is a very effective type for dealing with large volumes of rain-water. The arrangement of storage tank and filter will depend to a great extent upon the volume to be filtered, whether they require to be constructed upon sloping or upon level ground, and whether one or more services is required. If it is assumed that a large building is wholly supplied with rain-water, it would not be necessary to filter the whole of the water if two separate services were adopted; viz., one to supply filtered water for dietetic use, and the other unfiltered water for sanitary fittings (where the water is not likely to be used for human consumption), for laundry purposes, washing vehicles, and similar uses.

Bacteria are responsible for the purification effected by

sand filters, organic matter being oxidised by the action of nitrifying organisms. Efficient filtration largely depends upon the rate of flow through the filtering medium, and upon the condition of the film of organic matter which forms on the surface of the sand.

After a time a slimy matter clogs up the surface of a filter, and its filtering capacity requires to be increased; this is done by removing a thin layer of sand, which should be replaced after washing unless new sand is substituted. When a sand filter has been cleansed, or when it is new, water should be allowed to stand upon it for about 30 hours, in order that a film of matter may be deposited upon the sand before filtration begins. Where very pure water is required the first flow through a sand filter should be rejected, or utilised for some other purpose.

With regard to the depth of sand for a small rain-water filter, this should be about 1 foot, and deeper where practicable. Each square foot of filter surface will effectively deal with 30 to 40 gallons of rain-water per day, and even with these low rates the filter area for a large house would be comparatively small.

Fig. 175 gives a plan of storage tanks and filters, together with their connections, where rain-water is supposed to be chiefly utilised as the supply for a large building. Two hundred gallons of filtered water are required per day, and the storage tank T has a water capacity of 16,000 gallons, which represents 80 days' supply. A rain-water separator R is provided to exclude the first portion of the rainfall from the storage tank, and two filters are arranged to work independently of each other, in order that one may be in use whilst the other is being cleansed. The filters may be located at a much lower level than that of the storage tank, and the supply to each filter may be controlled by a ball-cock as shown. On the supply pipes to the filters three stop-cocks are indicated, which are numbered 1, 2, and 3, whilst two others are provided on the outlets of the filters and numbered 4 and 5. Stop-cocks 2 and 4, 3 and 5, serve to throw the filters out of action, whilst stop-cock No. 1 is intended to be set so as to regulate the rate of flow to the filter. Adjoining the filters a small storage

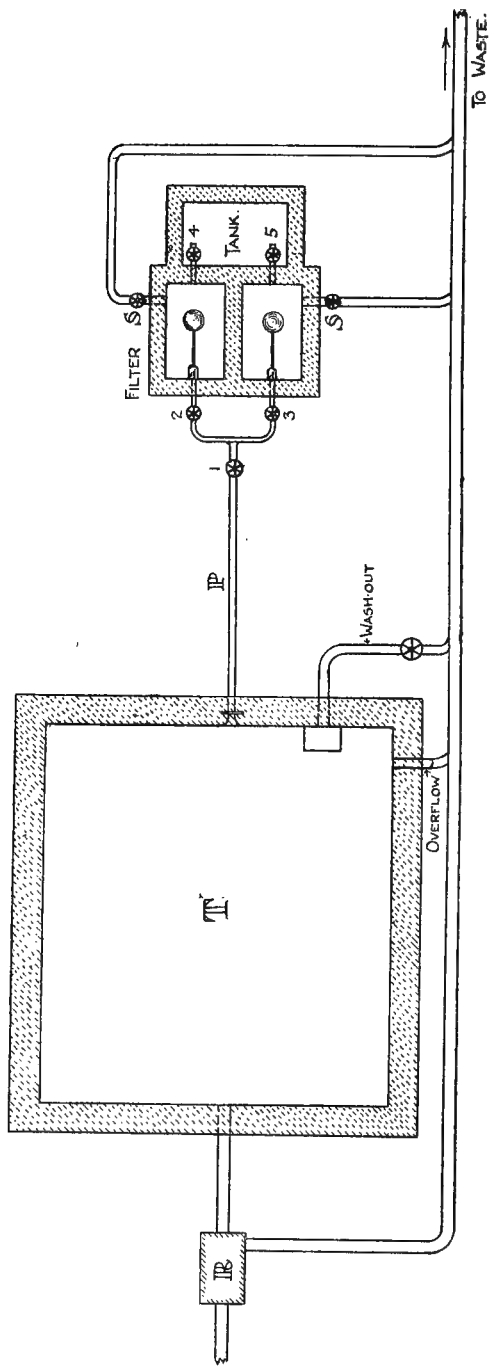


Fig. 175.—Plan of storage tanks and duplicate sand filters.

tank is provided for filtered water, which may hold rather more than one day's supply.

The construction of the filters is as follows:—On the floors perforated tiles are arranged, which allow the filtered water to flow into a channel, and thence to the small storage tank. About six inches of gravel are laid upon the tiles, and upon the gravel 1 foot of suitable sand is placed. To prevent the surface of the sand being disturbed by inflowing water, the ball-cocks may deliver into small earthenware channels which rest upon the sand; in this way the water would be better distributed over the filter.

A sump is provided at the outlet end of the large storage tank T, and here a sluice may be arranged in order that the tank may be emptied when desired. An overflow to the tank is provided, and is shown to discharge into the waste-water drain from the separator. The tanks and filters should be properly roofed over and ventilated, the walls and floor rendered water-tight, and ample means of access should be provided. Where concrete construction is adopted it can the more easily be rendered water-tight by properly grading the aggregate. A good concrete mixture for water-tight work is 1 part cement, 2 parts sand, and 4 of broken stone, the latter being broken to various sizes.

Where only a comparatively small volume of rain requires to be filtered, household filters would be the most satisfactory to use.

Springs as a Source of Water Supply.—As a rule springs yield a pure and wholesome water, on account of the latter having percolated long distances and filtered through considerable masses of earth. For houses in rural districts, springs form good sources of water supply, as the water yielded by them is usually free from organic impurity, although it may contain a large amount of carbonic acid gas and dissolved mineral matter.

There are two kinds of springs: (a) surface or intermittent springs; (b) permanent or deep-seated springs.

Surface Springs.—A surface spring may occur either at a low point on the side of a hill, or at the side of a valley, where an impervious stratum which prevents farther downward

progress of the water suddenly appears at the surface. When rain falls upon pervious strata at a high level it gradually flows downward and forward in its underground course, until it reappears at the outcrop. The volume of water yielded by a surface spring depends upon the area drained, and upon the percentage of the rainfall which percolates into the earth.

As their name implies, the volume of water yielded by surface springs is readily influenced by wet and dry weather.

Deep-Seated Springs differ from surface springs in that the water is forced to their outlets by more or less hydrostatic pressure, whilst the water of surface springs simply gravitates from a higher to a lower level, and is under no hydrostatic pressure. *Deep-seated* springs have their origin where the rain, after percolating through porous strata at a high elevation, eventually becomes confined between impervious strata and sinks to a lower level than its point of escape. The water of these springs usually travels long distances through porous rocks, and when it has reached its lowest point it there accumulates until sufficient pressure is produced to force it through some fissure in the strata. Owing to these large subterranean accumulations of water, deep-seated springs yield a more nearly permanent rate of flow.

Spring water is clear and sparkling, owing to its having filtered long distances through porous strata, and with having absorbed large volumes of carbonic acid gas in its passage. Where spring water is used for supplying one or more buildings in a rural district, a spring may frequently be chosen which is sufficiently high to give a gravitation supply by providing a suitable storage tank which either adjoins or is located some distance from it.

With regard to the size of storage tanks, in this case it will depend upon the volume of water yielded by the spring, whether the yield is fairly uniform or not, upon the volume of water required, and whether water is stored for extinguishing fires.

If the yield of a spring is greater than the demand, only a small storage tank may be essential; but if the demand for water at certain times greatly exceeds the rate of supply,

then a larger reserve will be required. Under the latter circumstances the capacity of a tank may be equal to anything from about 4 days' to 4 weeks' supply, according to the requirements to be satisfied.

The storage capacity for fire extinction cannot be definitely fixed for small supplies, as so much depends upon the special circumstances of each particular case.

Owing to the freedom of spring water from organic pollution, no further filtering of this water is usually required. The outlet pipe from a storage tank should be protected by either a copper rose or a wire screen, in order to prevent any foreign matter which may enter a tank from being drawn into the pipe.

A suitable overflow should be provided, and where a storage tank is large provision should be made for emptying it. If a spring be a large one, the supply to a storage tank may be regulated by a ball-cock, whilst in the case of a more limited supply the whole of the water may flow to the tank.

When springs occur at lower levels than the buildings to be supplied, great care is necessary to guard against possible pollution of the water. The usual appliances for raising water to higher levels are pumps and hydraulic rams, the latter being specially suitable where there is sufficient water to work them.

A simple method of finding the volume of water a spring will yield is that of first ascertaining by means of a stop-watch how long it takes to fill one or more buckets of known capacity.

A convenient place can usually be found where the stream from a spring may be impounded, and by means of a spout or channel (after the water-level has adjusted itself), the yield may be readily gauged, and expressed in gallons per minute or in any other units desired. Thus, if a bucket has a capacity of $2\frac{1}{2}$ gallons and is filled in 25 seconds, the yield = $\frac{2\frac{1}{2} \times 60}{25} = \frac{5}{2} \times \frac{60}{25}$ = 6 gallons per minute, or $6 \times 60 = 360$ gallons per hour.

Wells as a Source of Supply.—In country districts underground water often forms the principal source of supply, and where it does not issue in the form of a spring it is often

necessary to tap it by means of a well. The quality of well water is very similar to that from springs, and depends upon the nature of the strata through which it has passed. Well water, however, is very liable to pollution unless the wells are suitably located, properly constructed, and protected by covering them.

There are three classes of wells—

(a) Surface wells.

(b) Deep wells.

(c) Artesian wells.

Driven tube wells may be classified along with either surface or deep wells, according to the geological formation through which they are driven.

Surface Wells are those which are sunk in the subsoil,

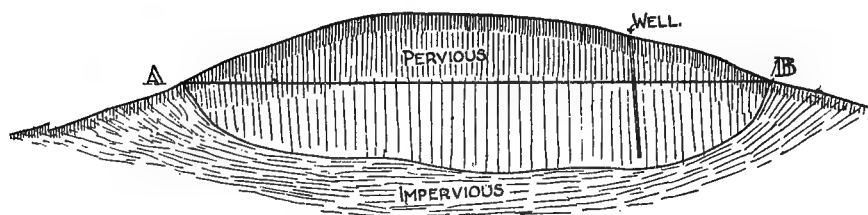


FIG. 176.—Subsoil well.

the water being held up by an impervious stratum as in Fig. 176. Rain after falling upon the permeable formation percolates downward until its progress is arrested, and the whole of the porous strata below the line AB is saturated unless water is withdrawn by pumping; any further water which percolates from the upper surface escapes at B in the form of a spring.

The chief objection to surface wells is, their waters are often exposed to sewage pollution, owing to leaky drains and cesspools, and by surface impurities being washed by rain into the subsoil; the waters yielded by surface wells are usually very hard, and not very suitable for general household use. So far, however, as the danger to pollution is concerned, this may be reduced to a minimum by making these wells in non-polluted areas, and by constructing the upper 12 feet of

their depth with water-tight linings, which are continued 9 inches or so above the level of the ground.

Driven Tube Wells.—In soft soils a cheap supply of water may frequently be obtained by an Abyssinian tube well. These wells are formed by driving strong iron tubes to near the water-bearing stratum. The usual sizes of the tubes are from $1\frac{1}{4}$ to 3 inches diameter, the difficulty of driving increasing as the sizes of the tubes are increased. To facilitate driving the tubes should not exceed 6 feet in length, and shorter ones in some cases may be desirable.

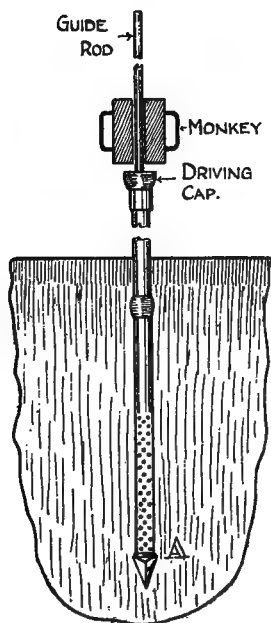


FIG. 177.—Method of driving tubes for an Abyssinian tube well.

The method of driving the tubes is chiefly governed by their size and the nature of the earth to be pierced. For driving the smallest sizes a sledge hammer may suffice, or the method shown in Fig. 177 may be adopted, where a weight or monkey falls on to a driving cap which is attached to the top of the tube. Where a heavy monkey is used it is raised by means of ropes and pulleys.

The first and perforated tube is 3 feet long, and is provided with a driving point, which is a little larger at A than the tube itself, in order that a hole may be made sufficiently large to just clear the sockets. In size the perforations are about $\frac{1}{4}$ inch diameter, but when the tubes are

driven into fine sand, the holes may be reduced in size by covering them with brass strainers. It is necessary when, first starting to drive the tubes to see that they are exactly vertical, otherwise the well may result in failure.

As each length of tube is driven in the ground another is added, and this process continues until the desired depth has been reached, when a pump is attached to the top of the

tubes. When, however, a well of the driven type is used its depth will be limited to about 30 feet.

Tubes can only be driven, of course, through soft loose strata, such as sand, fine gravel, etc., as in Fig. 178. Where firm strata is to be penetrated the hole for the tubes requires to be bored. After the tubes have been driven to the required depth, Fig. 178, a cavity requires to be made in which water may accumulate, or pumping would be difficult if water were drawn directly from the surrounding earth. The cavity may be formed by allowing the column of water in the tubes which form the suction pipe to fall back a number of times by destroying the vacuum, and so loosen the sand which surrounds the perforated tube. To aid in removing sandy matter which enters the tube it is better to use a common galvanised iron pump, as grit has a destructive effect upon the working parts of a pump. The vacuum in the suction pipe may be broken during the formation of a cavity by providing a short length of tube with a tee, and by temporarily joining

it at P, Fig. 178. A pump may then be screwed into the upper opening of the tee, whilst a stop-cock may be fixed to the remaining connection. After the pump has been primed and a few strokes made, the water rises to the outlet, when, upon quickly opening the cock, air is admitted and the water falls to loosen the earth surrounding the perforated tube. This operation can be repeated until the cavity is sufficiently large, and the temporary pump may be removed and the permanent one installed.

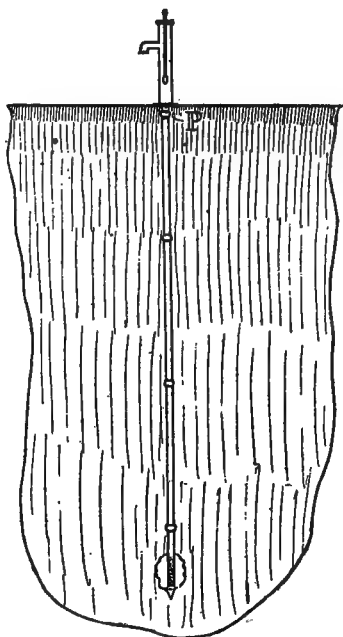


FIG. 178.—Abyssinian tube well.

Deep Wells differ from surface wells inasmuch as the latter only tap the subsoil water, whilst deep wells tap water which is located beneath the impervious stratum which sup-

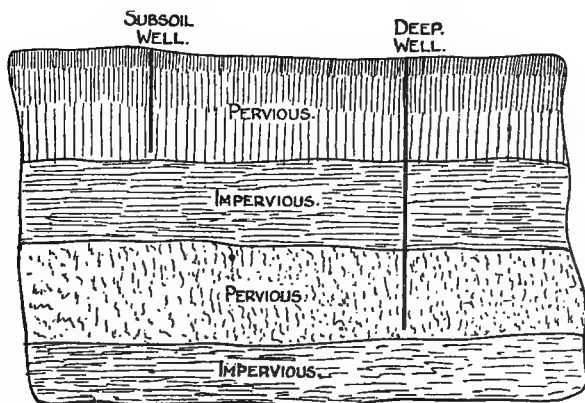


FIG. 179.—Formation showing subsoil and deep wells.

ports the subsoil water. The actual depth of a well does not decide the class to which it belongs, and a so-called surface or subsoil well in one locality might be much deeper than a so-called deep well in another district. Fig. 179 clearly shows the difference between surface or subsoil and deep wells.

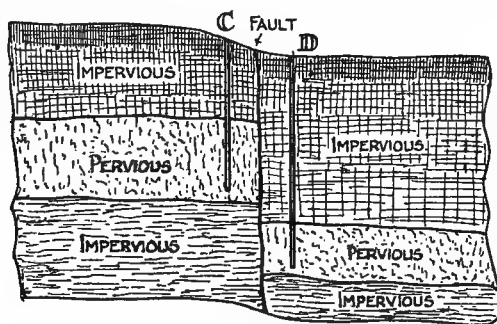


FIG. 180.—Formation showing fault.

Deep well water is usually very pure on account of its having filtered long distances, and by the protection afforded it by the overlying, impervious stratum. It is essential,

however, where deep wells are constructed, to have the whole of their linings watertight in the subsoil and to exclude surface impurity.

The amount of water yielded by a deep well depends upon the area of the outcrop, and upon the volume of rain which enters it, upon the dip of the strata, upon the depth of the well, and whether the geological formation is free from faults.

Fig. 180 shows the effect a fault may have. The impervious stratum on the right side of the fault imprisons water in the porous strata on the left side, owing to the dip of the underlying impervious stratum being in the direction shown. A well sunk at C would thus yield water, whilst one at D would result in failure owing to the underground flow being cut off by the fault. Even if it is assumed that a little water may be found at D, it would readily be drained by a well which was sunk at a lower point to the right of the fault.

Bore-Holes.—When it is necessary to penetrate the earth to great depths through hard strata in order to obtain water, bore-holes, Fig. 181, are often resorted to. In their upper and enlarged part the air-vessels and connecting rods are arranged. Bore-holes vary from 4 inches diameter to over 36 inches diameter, and their depth may range from 40 to over 2000 feet.

Artesian Wells.—The water in artesian wells is under hydrostatic pressure, and owing to the impervious strata being pierced under which the water is confined, the latter rises to the surface and overflows at the mouth of the well. Fig. 182 shows a formation which produces an artesian well; the strata on each side outcrop at a high level, where the rain-water enters and percolates downwards to the lower level; here the water accumulates under pressure on account of the plane of satura-

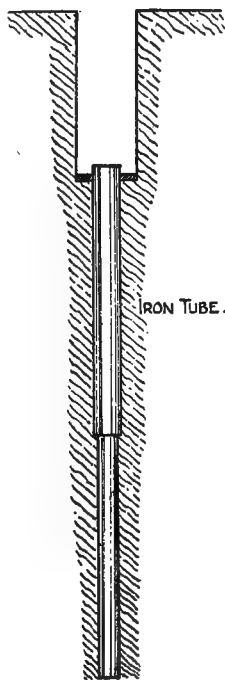


FIG. 181.—Bore-hole well.

tion occurring at a high level. If a bore-hole W, Fig. 182, is driven until it penetrates the lower permeable strata, water immediately rises and overflows the top of the bore-hole. In other cases water may be unable to rise to the top of the well, but it may rise in the bore-hole to a considerable height, and by so doing reduce the cost of pumping.

Upland Surface Water is frequently obtained from uncultivated mountain regions, which are well removed from the abode of man. This water is usually soft and free from animal pollution, but in times of storm it is often discoloured, and if it flows over peaty surfaces acidity is imparted to the water, and this frequently causes it to attack lead pipes.

River Water as a rule does not prove an ideal supply, but in some cases it is the only water that is available in

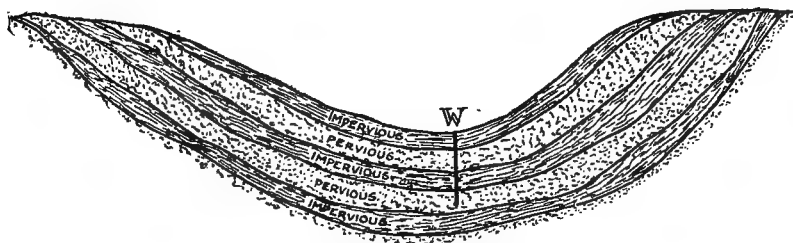


FIG. 182.—Formation producing an artesian well.

sufficient volume and at a reasonable cost. To render river water fit for drinking purposes it should be obtained from a point well above the line of pollution, and be subjected to sand filtration. As river and upland surface waters are only utilised by large communities, a lengthy treatment of these is beyond the scope of this work.

Hardness of Water.—The following is the order of different waters with regard to their softness:—

1. Rain water.
2. Upland surface water.
3. River water.
4. Spring water.
5. Deep well water.
6. Shallow well water.

Although we speak of water as being “hard” or “soft,”

these terms are only relative ones, as most soft waters contain a certain amount of hardness. Hardness in water is measured in degrees, a degree of hardness being equal, according to Dr. Clarke's scale, to 1 grain of bicarbonate of lime in 1 gallon of water. The amount of hardness in water is frequently determined by standard soap solution.

Hard water is readily known by the manner in which it curdles soap, and by its characteristic roughness to the skin. *Soft water*, on the other hand, feels smooth to the touch, and forms a free lather with soap.

In general, *soft water* is understood to be water which contains not more than 5 degrees of hardness, and *hard water* that which contains more than 5 degrees.

As rain is the primary source of all our water supplies, all waters are at the outset soft, and hardness is produced by their dissolving traces of mineral matter when either percolating through the earth or when flowing over the earth's surface. Hardness is of two kinds, one being termed "temporary" and the other "permanent."

Temporary hardness is principally due to lime salts when in the form of bicarbonate of lime, the bicarbonate being held in solution by carbonic acid gas. In the absence of this gas water will only dissolve traces of carbonate of lime.

Permanent hardness is chiefly caused by the water dissolving sulphate of lime, which may take the form of spar or gypsum. It differs from temporary hardness inasmuch as sulphates are dissolved in either the presence or absence of carbonic acid gas, the latter not being in any way responsible for sulphates passing into solution.

A water moderately hard is advantageous for dietetic purposes, but for laundry uses a certain amount of soap must be decomposed to remove the hardness before a lather can be formed. Hard waters also give trouble in boilers, and in their connections, by causing earthy matters which produce the hardness to be precipitated and to form a scale that adheres to the surfaces of pipes and boilers. In the case of a hot-water heater which is supplied with temporary hard water, the latter upon having its temperature raised to about 200° F. causes the carbonates to be deposited. If, on the other hand,

the same heater was supplied with water containing permanent hardness, the raising of the water to 200° F. would have practically no effect upon the hardness. Should, however, the temperature of the water be raised to 300° F. and over, some of the sulphates may also be precipitated.

A steam boiler differs from a hot-water heater, for in the former the water is evaporated, and in consequence turns out both forms of hardness.

Softening Water.—On account of the general advantages derived by the use of soft water, the softening of hard water is often resorted to. Certain industries, for example, can only be carried on with soft water, but these when conducted on a large scale are usually located in districts that have a suitable water supply. The methods adopted for softening water are by boiling it in a suitable apparatus, and by chemically treating it. The first method is limited to the softening of temporary hard water, whilst the other may be adopted for reducing either temporary or permanent hardness.

The more simple method of softening water is by boiling it, as only a single operation is involved. While, however, this method is very suitable for both sterilising and softening small volumes of temporary hard water, it would prove a very expensive operation when dealing with large volumes for industrial purposes; in many cases softening by boiling would be impracticable.

Softening by means of suitable chemical reagents is the general method adopted, when either treating the whole of the supply for a district or only a limited volume of water for industrial uses. For a chemical process to be successful, the reagents must be added in the correct proportions, and be thoroughly mixed with the water to be treated; provision is also necessary to prevent carbonates settling out of the treated water and causing deposits in pipes and in their connections.

When lime in the form of lime-water is used as the reagent for removing temporary hardness, the lime absorbs the carbonic acid gas, for which it has a great affinity, and the carbonates are precipitated chiefly in the form of carbonate of lime.

As many waters contain both temporary and permanent hardness, the removal of the latter is accomplished by adding

other reagents which decompose the earthy matter producing the hardness.

A method of softening water by The Pulsometer Engineering Company is given in Fig. 183. At the highest point a tank is provided, which is divided to form a large and a small compartment; the larger one regulates the volume of water to be treated at one time, and is provided with a siphon to automatically effect its discharge when full of water. Prior to the water being discharged it overflows the division, and fills the smaller compartment; the outlet valve in the latter is controlled by the lever shown, which in turn is operated by the rising and sinking of the float. To the outlet of the smaller compartment of the upper tank a pipe is joined, the other end of the pipe being connected to the bottom of the smaller cylindrical tank, which contains the lime-water. Another small tank contains a solution of soda, or other suitable reagent, which is used in measured doses by means of the bucket which is connected with the lever. The bucket is filled with the soda solution upon being submerged by the rising of the float in the large compartment. To effect the discharge of the solution from the bucket a small Wertenburg siphon is employed, the outlet end of which delivers into the mixer. The outlet from the large tank and that from the lime-water tank also discharge into the mixing chamber, which is located at the top of the large settling tank. From the mixing chamber a pipe is taken, and its lower end terminates near the bottom of the settling tank; from the latter an outlet pipe is joined to the upper part of a filter, which is placed beneath the lime-water tank.

The working of the softening plant is as follows:—As the water to be treated fills the upper tank, the float at the same time rises and operates the lever to lower and submerge the bucket in the soda tank; as the water continues to rise in the float compartment it eventually overflows to fill the adjoining compartment until a given point is reached, when the siphon is brought into action and the contents of the tank are discharged. Simultaneously with the discharge of the water from the large tank the valve in the smaller compartment is opened, when its contained water displaces an equivalent

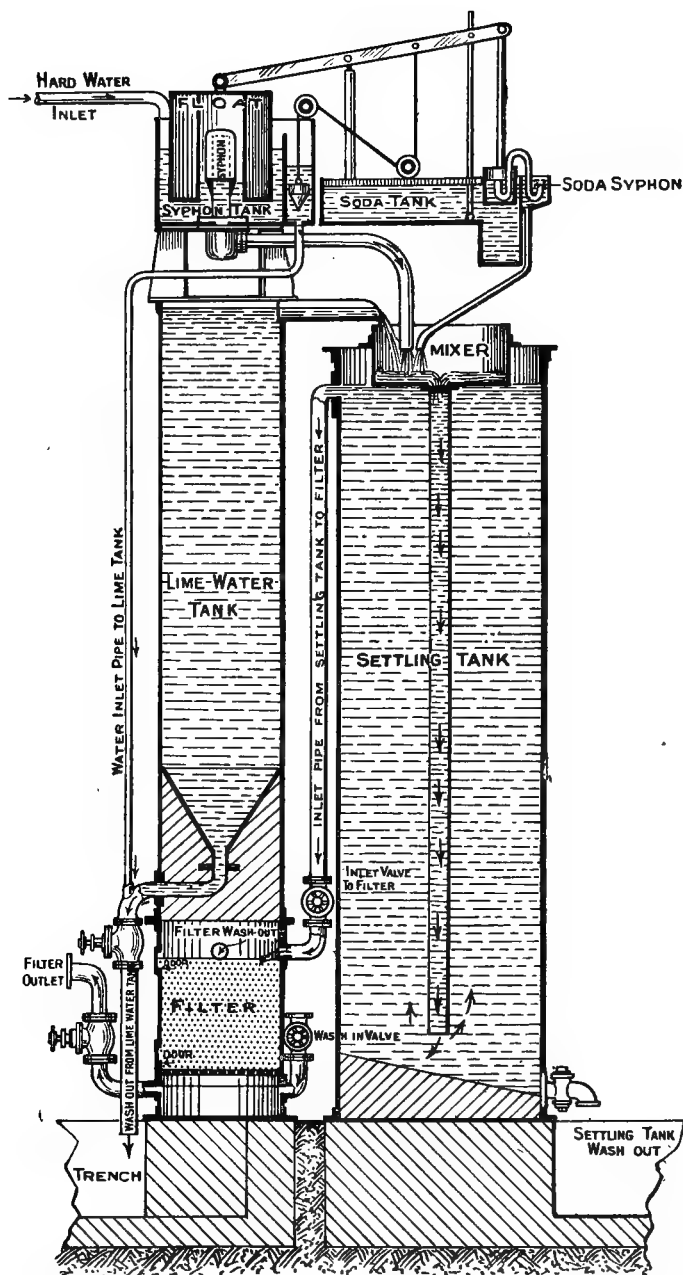


Fig. 183.—The Criton water softener (Pulsometer Engineering Co.).

volume of lime-water from the cylindrical tank beneath. The bucket which has received its charge of soda solution is gradually raised by the falling float, and the discharge of the solution begins by the small siphon coming into action. By the simultaneous discharge of water and the chemical reagents into the mixing trough the whole are mixed together and flow to the bottom of the settling tank. In the latter tank the greater percentage of the salts settle out of the water, and they are precipitated in the form of mud. From the settling tank the treated water flows to the filter, and any carbonates, etc., which remain in suspension are intercepted on the surface of the filtering medium. At the bottom of the settling tank a stop-cock is provided which admits of any excess of sludge being withdrawn. The periodical cleansing of the filter is accomplished by admitting water under pressure through the valve at the bottom of the filter, when its upward passage displaces the deposited matter from the filtering medium, and both escape at the washout provided at the top of the filter.

To produce the lime-water, slaked lime is first placed in the lime-water tank, and during the upward passage of the water the latter becomes saturated with lime. Fresh lime is added daily or as required, the old or spent lime being discharged by opening the wash-out valve.

The soda solution is of known strength, and is added when it is found necessary.

The Archbutt-Deeley Process of softening water is one that has been largely adopted. In this system square or rectangular tanks are used, their depths varying from 7 to 10 feet. The chemicals used are similar to those employed in the system already described, but the two installations differ considerably in design and in the mode of operation. In the "Criton" softener, Fig. 183, the chemicals are added automatically, whilst in the Archbutt-Deeley process no attempt is made to render the installation automatic in action, and the chemicals are added by an attendant.

In the latter system, after a tank has been filled to the desired height with hard water, the chemical reagents are caused to be diffused throughout the whole body of the water by the aid of perforated horizontal pipes, in conjunction with a

circulating arrangement which is operated with "live" steam. To accelerate subsidence in the treated water some of the previous precipitated matter is caused to be stirred by blowing air through perforated pipes, which are fixed near the bottom of the tank, and the water is afterwards allowed to remain quiescent for about an hour or so whilst precipitation takes place. The softened water is then withdrawn from the surface of the tank by means of a hinged floating arm in connection with the outlet valve.

To prevent carbonates settling out of the softened water the latter is carbonated. This is effected with carbonic acid gas, which is produced by a coke stove, by causing the gas to come in contact with the water as the latter flows from the softening tank.

There are many other types of water softening apparatus in use, but for any type using chemical reagents to be satisfactory the chemicals require to be added in correct proportions and strengths, and to be thoroughly mixed with the water to be treated.

Constant, Partially Constant, and Intermittent Supplies.—

The value of a constant water supply is generally recognised; the water being always on under pressure in the street mains—excepting when repairs or alterations are being effected—can be withdrawn in a fresh condition, whilst storage cisterns are not essential, and the possibility of pollution is much less than with any other form of supply.

An intermittent supply may be due to—

- (a) Insufficiency of water to maintain a constant supply;
- (b) Draw-off taps being located in elevated positions relative to the source of supply;
- (c) The mains being too small to supply higher levels when there is more or less considerable draught upon them at lower points.

Under the latter conditions the supply may be termed a "partially constant" one, as the failure of the supply may only occur with an abnormal draught during certain periods of a day.

Very often the term "intermittent" is confined to supplies where the water is only turned on to the consumers for a

number of hours each day, although such measures may only be necessary at certain times each year when the supply is running short. In partially intermittent supplies there may be no lack of water at the source, but the distributing mains may be inadequate at certain periods to meet the demand upon them.

Arrangement of Service Pipes.—The kind of supply naturally regulates to a great extent the general arrangements of service pipes. For example, where a water supply to a building is on the constant system, all draw-off taps from which drinking water is drawn should be supplied directly from the street mains. Where there is considerable pressure of water it is often desirable to supply the cold draw-off taps to baths and similar fittings, especially in large buildings, from an overhead storage cistern, in order to avoid undue wear and tear upon the water fittings.

In the case of an intermittent supply it is necessary to serve the whole of the fittings from storage tanks, and the service pipes require to be large enough to fill the cisterns during the period the water is turned on. Should a supply be a partially constant one, some of the draw-off taps will necessarily require to be supplied from a storage tank, whilst others may be directly connected with the house service pipe.

In high buildings it becomes necessary under certain conditions to supply the taps on the upper floors from cisterns, whilst those at lower levels may have a constant or direct supply. For dwellings where a constant supply cannot entirely be relied upon, a direct supply from a street main and a supply from a storage cistern can with advantage be laid on to each kitchen or scullery sink.

The drawbacks of cistern supplies are: the water loses its freshness, and is liable to pollution by foreign matter gaining access to a cistern unless precautionary measures are adopted.

With regard to the sizes of service pipes, those of $\frac{1}{2}$ inch diameter may be considered the minimum for ordinary dwellings which have a constant supply, whilst a larger size is essential where the supply is an intermittent one.

Water companies, to whose system service pipes are to be

joined, often stipulate the sizes of the pipes necessary for different buildings, but the sizes of service pipes may be calculated for special cases, provided the necessary data are available.

In large buildings where provision is made for extinguishing fires, or where large volumes of water are necessary for trade purposes, the supply pipes may require to be from 3 to over 6 inches diameter.

As far as possible water pipes should be placed beyond the reach of frost by fixing them on the inside walls of buildings, and by laying them in the ground to a minimum depth of 2 ft. 6 in. When it is imperative to fix water pipes in exposed situations they should be well protected by a thick covering of hair felt or other suitable insulating material.

In many buildings pipes can be arranged that they may be emptied of water by making them fall to given points, where draw-off taps should be provided. In order to empty water pipes, air requires to be admitted at the higher points, after the stop-cocks are closed. This method of preventing damage to water pipes by frost can advantageously be adopted for buildings or those portions which are not used during the winter months.

A Stop-Cock should always be fixed on a service pipe at a point near to the boundary of a building, and an additional stop-cock is desirable on each service pipe just inside a building, so as to enable the water to be turned off when it is desired.

In small houses which are arranged in terrace form, and for tenement buildings, one service pipe is often common to a number of dwellings, and under these circumstances the branch services should be separately controlled by stop-cocks.

For large buildings, where the control of the water supply in any section of them is of importance, every principal branch should be provided with its own stop-cock.

Underground Stop-Cocks should be made as accessible as possible. A good method is that of fixing a permanent wrought-iron key to the crutch of the stop-cock, and the key should reach nearly to the top of the stop-cock eye, which finishes flush with the road surface, as in Fig. 184. An eye is usually built with bricks, but in many cases it may be formed

with a 6-inch or a 9-inch drain pipe, which rests upon a firm foundation. Permanent keys may not be desirable for all situations, but where a stop-cock is likely to be interfered with a loose key should be provided.

Both the plug and screw-down types of stop-cocks are used for service pipes, but the latter is the more generally used. Each class of cock, however, has its merits and drawbacks. The points in favour of screw-down taps are they can only be slowly closed, concussion is avoided, they are more easily repaired, and they are cheaper than plug taps.

The principal drawbacks of screw-down taps for underground situations are:—their relative weakness, liability of leakage at the stuffing boxes, and unless discretion is exercised in closing them with keys which have a large leverage, the top of the taps is liable to be broken. The omission of a set screw in a screw-down tap has occasionally resulted in the top being screwed off when inadvertently opening it.

With regard to the merits of plug taps when located underground, they are stronger and less liable to leakage than screw-down forms.

The principal drawback of plug taps is the excessive strain to which the pipes are subjected when the taps are quickly closed. This drawback, however, does not always exist, and in the case of underground taps they usually get stiff to turn through infrequent use, and therefore do not admit of being quickly closed.

Connections of Service Pipes with Street Mains.—Service pipes are joined with tapping mains when either the water is on under pressure or when the mains are emptied of water. The appliance used (Fig. 185) for joining service pipes with

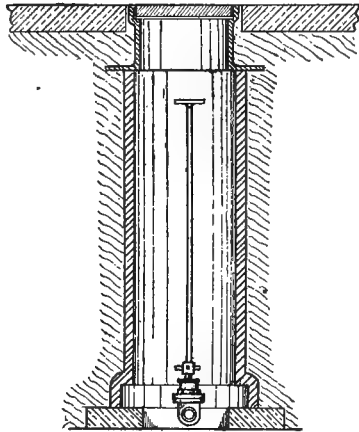


FIG. 184.—Stop-tap eye and cover.

a main when the water is on under pressure contains two

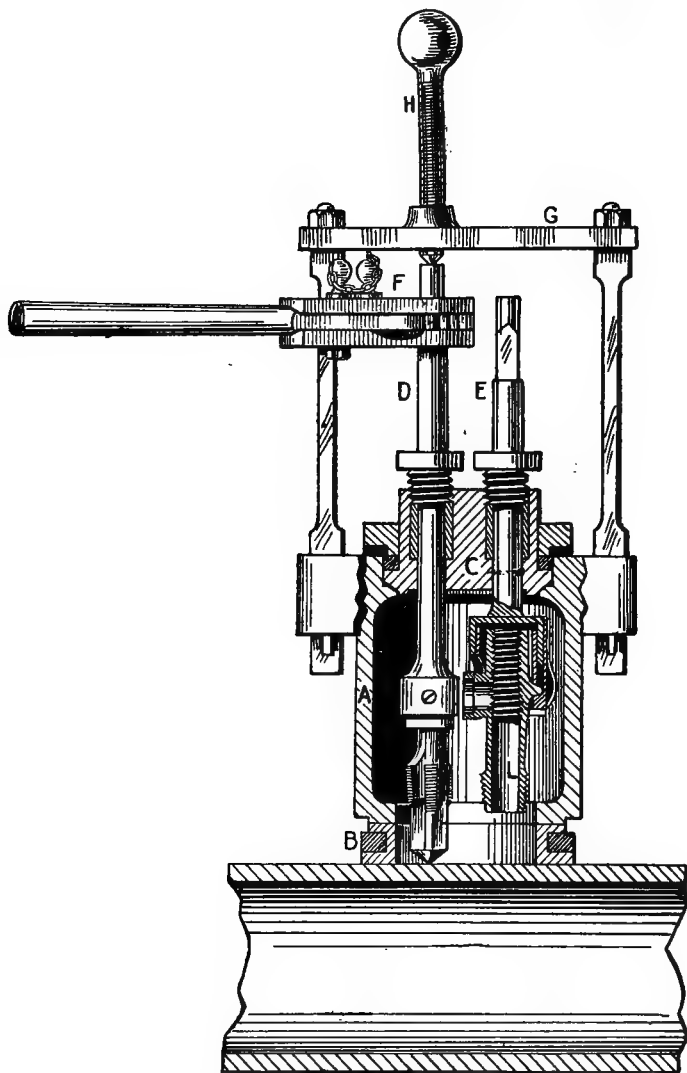


FIG. 185.—Apparatus for drilling and tapping water mains when under pressure (Palatine Engineering Co., Liverpool).

principal parts: one part holds a combination drill and screwing tap, for cutting and preparing the hole in the iron main at one

operation; the other part holds a stop-cock ferrule L, which is screwed into the tapped hole after first moving it to the position previously occupied by the drill. The appliance, when properly fixed on the main, forms a water-tight joint, and, owing to the movable spindles D and E working through stuffing boxes, little water escapes during the process of drilling and tapping of the mains.

Storage Cisterns which are fixed in the higher parts of buildings may be formed of earthenware, slate, wrought and cast iron, mild steel, and of woodwork when lined with suitable sheet metals.

Glazed earthenware, or porcelain, cisterns possess the advantage of being easily cleansed, and they are also free from corrosion. Their weight is their chief drawback.

Slate cisterns, like those of porcelain, are free from the corrosive action of certain waters, and if properly jointed are suitable for storing drinking water. As slate cisterns are formed of slabs which are grooved and bolted together, they are convenient for hoisting into their respective positions. It is very important, however, when fixing slate cisterns to have a firm floor on which they may rest, or there will be difficulty in making them water-tight. Another important matter is to prevent water from coming in contact with the red and white lead jointing materials when the water is to be used for dietetic purposes; this, however, can readily be done after the surplus material has been removed by applying a coat of hot liquid pitch over the joints.

Mild steel and wrought iron are often used for large tanks which are required to resist more or less considerable pressure. Should these materials be unprotected, however, they are rapidly corroded by soft water, mild steel being the more readily attacked of the two.

Galvanised sheet-iron tanks are largely used for storage purposes on account of their comparative cheapness, and where water contains temporary hardness galvanised iron has a long life, and has no prejudicial effect upon such water. Soft acid waters, however, corrode iron which has been galvanised, the rate of corrosion being accelerated by galvanic action. The action of certain waters upon galvanised iron

in some cases is most marked, thin sheets being perforated by corrosion within two or three years.

Cast-iron tanks when large are built up in sections, which as a rule do not exceed 3 feet square. Flanges are cast on the sections, and these are frequently planed so as to enable the joints to be the more readily made. For planed joints, red and white lead jointing materials are generally adopted, and for ordinary joints rust cement is used. Large tanks require to be well stayed, or they may fail when filled with water. As a rule smaller sections than the size stated are desirable, as the flanges impart stiffness and strength to the tanks. In thickness, the plates vary from $\frac{3}{8}$ inch to 1 inch, according to the pressure they are required to withstand and according to the size of a plate.

Wood cisterns with lead linings can readily be made to suit any particular position with regard to shape, and lead is not affected by corrosion to the same extent as iron. These cisterns are very suitable for storing water for general purposes, but when drinking water is to be stored another form of lining should be used.

Copper-lined cisterns possess the same advantages as those with lead linings, excepting that the former may be a little more costly. If the copper is tinned the tanks have a clean appearance, they are very durable, and very suitable for storing drinking water which contains temporary hardness. Where lead and copper linings are used for wood cisterns, the latter require to be substantially constructed so as to prevent their yielding at the joints by the continuous thrust of the water.

Closed Pressure Tanks may with advantage be used in many cases. As ball-cocks are discarded, and the tanks communicate directly with the street mains, the tanks require to be strong enough to safely resist the maximum water pressure. Pressure tanks (Fig. 186) are constructed in either galvanised wrought iron or in mild steel, the thickness of the metals being governed by the diameter of the tanks and the maximum internal pressure they are called upon to withstand. At the top of the tank a float valve and air strainer are provided, the latter being simply an enlargement in the pipe,

which is filled with cotton wool or other suitable material. The float valve may simply consist of a composition ball which is buoyed up to close an orifice when the tank is full of water, but the valve remains open when the tank is filling so that air can escape. At a low point in the service pipe a non-return valve is fixed, in order to prevent water flowing back from the storage tank to the street main. Above the non-return valve, branches are taken from the service pipe in the ordinary manner, and by means of the bib tap shown the pipes above that level can be emptied of water.

An advantage possessed by the arrangement Fig. 186 is that it allows water to be obtained directly from the street main when the pressure at the point of withdrawal exceeds that due to the head of water in the tank. When the pressure in the main fails, water is available from the storage tank.

Safes.—When there is any possibility of damage being done by leaking cisterns, it is usual to place them upon lead safes. These are simply pieces of sheet lead which are turned up a few inches all round, so as to form a tray or shallow box. Slate cisterns

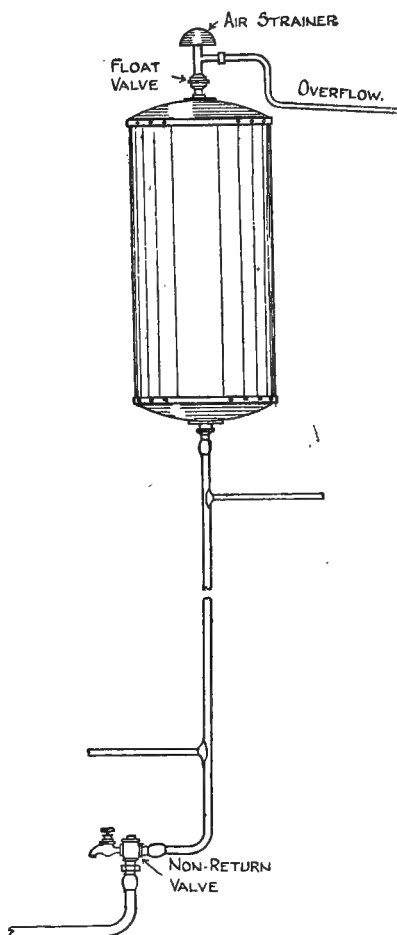


FIG. 186.—Harding's pressure tank arrangement.

should always be fixed upon lead safes, owing to their liability to leakage. The waste pipes from safes must not be joined with any other waste pipe, but like overflow pipes discharge directly into the open air.

Cistern Overflows.—In frosty weather, when the ends of overflow pipes terminate in the open air, a stream of cold air generally flows into the apartments where the cisterns are located, and aids in freezing the water both in the pipes and cisterns. To obviate this, the ends of overflow pipes are sometimes protected with light hinged copper flaps, as in Fig. 187. At A the end of the pipe is cut splayed with the flap resting upon it, whilst at B the end is trimmed that the

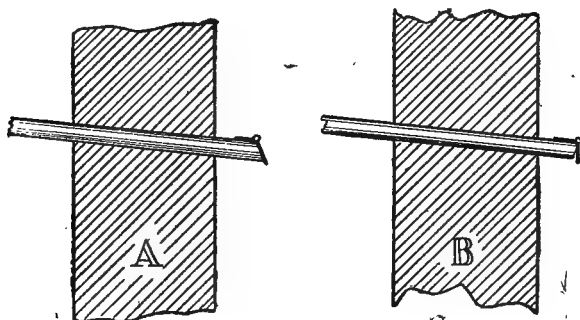


FIG. 187.—Cistern overflow pipes.

hinged flap may hang a little open. In the latter case the flap is intended to close the orifice when the air tends to flow into the cistern apartment through the overflow pipe.

Flap valves for overflows are made in different forms to suit either iron or lead pipes; those shown are for lead pipes, and are made secure by soldering them. The method of fixing the flap as shown at A, Fig. 187, should not be adopted, as it is liable to stick, especially in frosty weather, when the overflow may be rendered inoperative and cause flooding.

Overflows should be large enough so as to discharge the water from cisterns as quickly as it enters them, and for small cisterns where the overflow pipes are moderately long it is usually desirable to give them an immediate drop, close to the cistern, as in Fig. 188.

Washouts.—Where large cisterns are required it is usually essential to make special provision for emptying them. In Fig. 189 the washout is shown joined with the overflow pipe, and it is controlled with a clear way stop valve.

An ordinary standing waste is given in Fig. 190, which can be removed when desired for emptying the tank.

As it is necessary for washouts to discharge into a drain or other suitable channel, tell-tale overflows should be arranged to come into use before the larger overflow pipes. For example, if a cistern supply pipe is 4 inch diameter, as in Fig. 189, the tell-tale overflow would immedi-



FIG. 188.

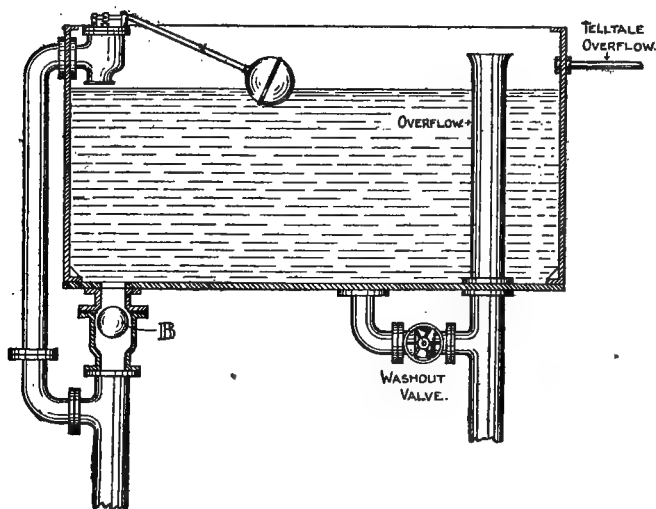


FIG. 189.—Arrangement of pipes in connection with large storage tanks.

ately indicate when the ball-cock was out of order, whilst the larger overflow would come into use later if required. In Fig. 190 the cistern is filled by pumping the water, and a tell-tale overflow of say half an inch diameter should discharge near to where pumping operations are conducted, to indicate

when the cistern is full, unless some other form of indicator is used.

When a washout discharges at a relatively low point, as in Fig. 190, the outflow of water may be considerably retarded by ventilating the vertical stack of pipes as shown. Precautions should be taken to prevent the trap at the foot losing its seal, and the pipe on no account should directly discharge into a foul-water drain.

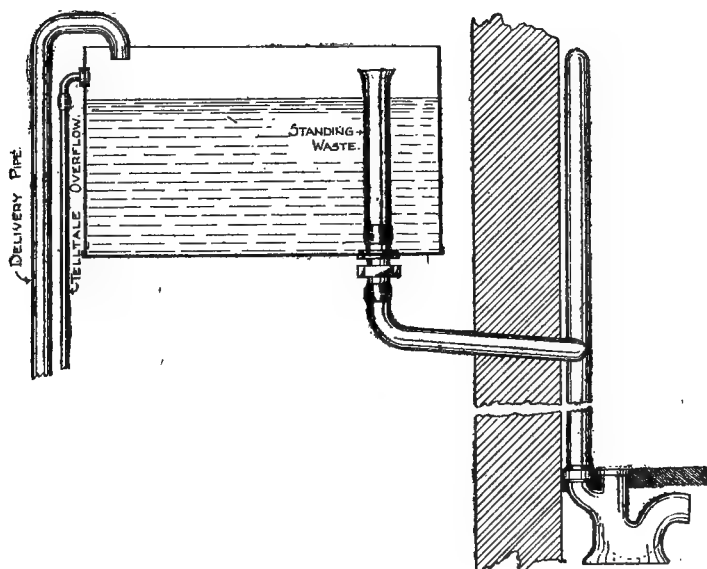


FIG. 190.—Large storage tank showing inlet and outlet pipes.

Fig. 189 shows how the supply and draw-off in connection with a large cistern are often arranged; the ball B closes the outlet orifice from the tank when the water is on under pressure, but allows water to be withdrawn from the tank when the supply to the latter fails.

Rules for determining capacities and sizes of cisterns.

Let G = capacity of cistern in gallons.

„ l = length of cistern in feet.

„ b = breadth of cistern in feet.

„ h = depth of cistern in feet.

$$\text{Then } G = l \times b \times h \times 6\frac{1}{4} \quad . \quad . \quad . \quad . \quad . \quad (20)$$

$$\text{and } l = \frac{G}{b \times h \times 6\frac{1}{4}} \quad . \quad . \quad . \quad . \quad . \quad (21)$$

$$b = \frac{G}{l \times h \times 6\frac{1}{4}} \quad . \quad . \quad . \quad . \quad . \quad (22)$$

$$h = \frac{G}{l \times b \times 6\frac{1}{4}} \quad . \quad . \quad . \quad . \quad . \quad (23)$$

Should a storage tank take an irregular shape, as in Fig. 191, to fit some required position, the following formulæ may be used:—

$$G = (n + o) \times b \times h \times 3\frac{1}{8} \quad . \quad . \quad . \quad . \quad (24)$$

$$b = \frac{G}{(n + o) \times h \times 3\frac{1}{8}} \quad . \quad . \quad . \quad . \quad (25)$$

$$h = \frac{G}{(n + o) \times b \times 3\frac{1}{8}} \quad . \quad . \quad . \quad . \quad (26)$$

Where n and o = the length of the short and long sides respectively.

Example 9.—If Fig. 191 represents the plan of a cistern where $n = 3$ ft. 8 in., $o = 4$ ft. 2 in., width 2 ft. 4 in.; find its contents in gallons if its depth is 3 ft. 6 in.

$$\text{By rule 24, } G = (n + o) \times b \times h \times 3\frac{1}{8},$$

$$G = 7\frac{5}{8} \times 2\frac{1}{3} \times 3\frac{1}{2} \times 3\frac{1}{8},$$

$$G = \frac{57575}{288};$$

$$\therefore G = 199\frac{2}{3}\frac{5}{8}, \text{ or say } \underline{200 \text{ gallons.}}$$

Example 10.—Determine the depth of a cistern which is similar on plan to Fig. 191, to hold 250 gallons, where $n = 4$ ft. 6 in., $o = 5$ ft., and the width is 2 ft. 7 $\frac{1}{2}$ in.

$$\text{By rule 26, } h = \frac{G}{(n + o) \times b \times 3\frac{1}{8}},$$

$$h = \frac{250}{9\frac{1}{2} \times 2\frac{5}{8} \times 3\frac{1}{8}},$$

$$h = \frac{1280}{399};$$

$$\therefore h = 3\frac{8}{9}\frac{8}{9} \text{ ft., or } \underline{3 \text{ ft., } 2\frac{1}{2} \text{ in. deep.}}$$

The actual capacity of storage tanks with an intermittent supply should not be less than twenty-four hours' requirements, and a greater reserve may be necessary in certain instances, but each case requires to be dealt with on its own merits.

Domestic Filters.—If drinking water is of doubtful purity the best plan is to boil it. This method, however, is not always convenient or practicable, and, moreover, water which has been boiled has a flat, insipid taste on account of its lack of aeration.

Various forms of household filters are largely used for filtering water, but very few are satisfactory, and the best

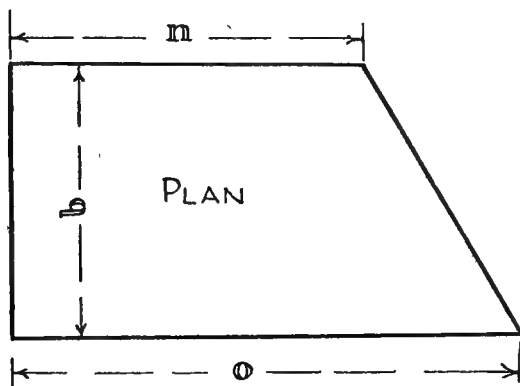


FIG. 191.—Plan of a cistern.

types only resist the passage of micro-organisms for a limited period.

Many domestic filters simply remove suspended and dissolved organic matter, but allow the free passage of germ life. As a rule where a good class of water is supplied on the constant system no filter should be used, as there is the possibility of the filtered water from a bacterial point of view being inferior in quality to the same water when unfiltered. If, on the other hand, a water supply is not beyond suspicion the filtration of water for dietetic uses may be found desirable. In the latter case it is important that a suitable filter be selected, and that it is regularly cleansed and sterilised to keep it in a satisfactory state.

Domestic filters may be divided into two classes. First, those which work under high pressure; and second, those which operate with a low pressure. The filtering medium may be the same in each type, the latter requiring a much larger surface of filtering medium.

Amongst the most reliable domestic filters are those of the

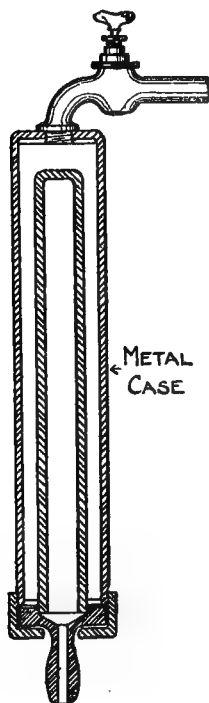


FIG. 192.—Pasteur filter.

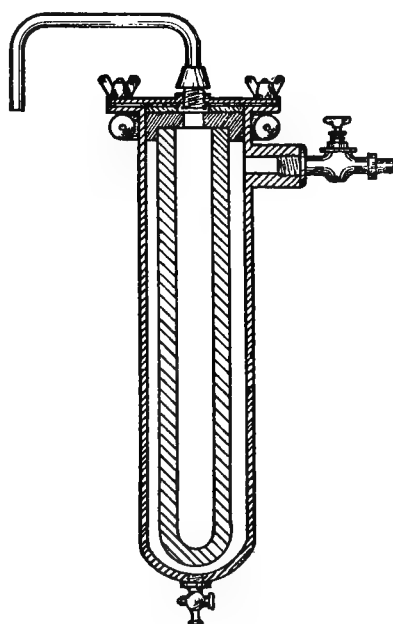


FIG. 193.—Berkefeld filter

Chamberland Pasteur, Berkefeld, and similar types. Figs. 192 and 193 show the filters mentioned, and in both forms the filtering medium takes the form of a cylinder or hollow candle, fine unglazed porcelain being used in the case of the Pasteur filter, whilst compressed silicious earth is used for the filtering medium of the Berkefeld.

The construction of the filters is clearly shown, and in

each case the water enters the metal cylinder and is forced under pressure through the porous medium, when it afterwards escapes through the glazed nozzle outlet in the case of the Pasteur, and through the bent tube at the top of the filter in the Berkefeld. The filtering medium in the Berkefeld is both thicker and more porous than that in the Pasteur, and the former consequently filters water at a quicker rate.

To cleanse these filters the candles are removed, washed, sterilised by boiling them, and afterwards replaced. Owing to the slow rate of filtration by a single Pasteur filter a small reserve of filtered water is desirable. For this purpose a glass or stoneware jar, which is fixed immediately beneath and connected with the filter, is generally adopted. Water may then be withdrawn directly from the receiver, but precautions are necessary to guard against contamination, as filtered water readily absorbs any gases to which it may be exposed.

For low-pressure filters of the Pasteur and Berkefeld types, several candles are arranged inside a large metal casing or cistern, the candles being joined to one common channel into which the filtered water escapes. As a number of joints are necessary with this arrangement, there is a possibility of some defect occurring through which unfiltered water may gain access to that which has been filtered.

Domestic filters to be satisfactory must be simply constructed, and admit of being readily taken to pieces for cleansing purposes. After a filter has been in use for some time, its filtering capacity is greatly reduced owing to the choking of the pores, but its normal rate may be again restored by thoroughly cleansing it.

Water Fittings.—Taps, cocks, cranes, or valves may be roughly divided into three classes :—

1. Those which automatically regulate the outflow of water.
2. Those which are operated by hand.
3. Those which are semi-automatic in action.

To the first class belong ball-cocks which are opened and closed by the falling and rising water in a cistern. To the second class the various forms of screw-down and plug taps belong. To the third class belong those which are opened by hand, but are automatically closed either by the aid of springs

or by the water pressure, or by means of a weighted lever. As a large variety of fittings belong to each class, further subdivision becomes necessary in order to compare their relative merits and defects.

Ball-Cocks.—These taps, which belong to the *first class*, may be subdivided into high and low pressure forms. High pressure ball-cocks have often restricted water-ways, and where the latter are fairly large the levers are frequently compounded. Low pressure ball-cocks have large water-ways, and may either be constructed upon the equilibrium principle or with simple direct acting levers.

Much annoyance and inconvenience are caused from time to time by unsuitable ball-cocks being fixed in cisterns. Very frequently a form of high-pressure tap is connected with a low-pressure service, with the result that the cistern takes too long to fill. For flushing cisterns in connection with w.c.'s it is specially necessary that they fill rapidly, but this can only be accomplished by the selection of suitable taps for the pressure at disposal.

Should a low-pressure ball-cock be fixed on a high-pressure service, the former will either be often out of order, or rattling sounds will be caused, due to the oscillation of the lever when the tap is nearly closed. The latter action under certain conditions is readily brought about, owing to the force which operates to close the tap not sufficiently exceeding that which tends to open it. When oscillation of a lever has commenced the water pressure is increased to a more or less extent, according to the amount of concussion produced by the quick successive opening and closing of the tap.

Two common and good types of ball-cocks are given in Figs. 194 and 195, but they are only suitable on account of their restricted outlets for high-pressure services. In construction the principle is the same in each case, their difference being in the arrangement of the plug or piston C, which contains the washer. In Fig. 194 the piston moves horizontally, whilst that of Fig. 195 has a vertical motion, the water escaping from the latter by side passages which are not shown in the figure.

When water is under considerable pressure the ball-cocks

shown are somewhat noisy in action, especially when they are nearly closed owing to the water issuing with considerable velocity through their contracted orifices. This objection,

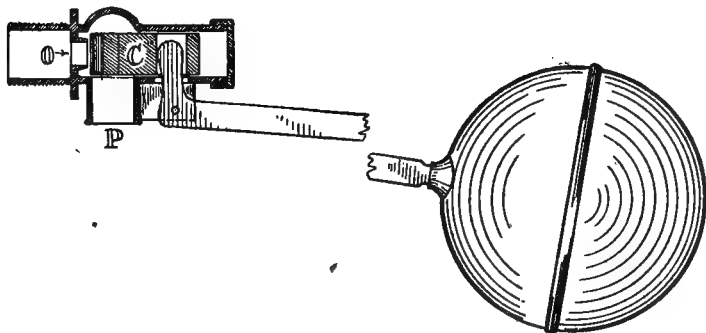


FIG 194.—High-pressure ball-cock.

however, can be overcome to a great extent by attaching to the outlet P of Fig. 194 a short length of tube in order that the point of escape may be submerged. Upon reference to Fig. 195 it will be observed that it does not admit of a silencing tube being readily attached, and this is the chief drawback of this pattern of ball-cock.

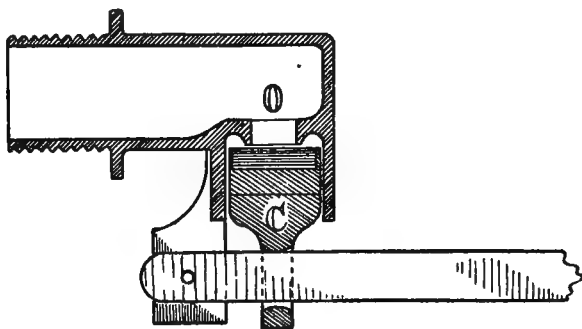


FIG. 195.—High-pressure ball-cock.

A patented form of ball-cock is given in Fig. 196, and in construction, the part containing the valve is similar to that in Fig. 195, excepting that the orifice O is larger. In Fig. 196 the additional power which is necessary to compensate for the larger valve orifice is obtained by compounding the

levers as shown. The regulating screw S is an advantage, for by its means the ball-cock can be adjusted with precision without resorting to the practice of bending the levers. It will be observed that the mechanical advantage of lever A is concentrated to operate on the adjusting screw S, which forms the end of the long side of lever B. From a practical point of view the advantage derived by compounding the levers of ball-cocks is very limited, and therefore for this type the size of the valve orifice for high pressures is also limited.

The full-way equilibrium valve Fig. 197 is well adapted for low pressures. In construction it differs considerably from the foregoing, inasmuch as the water pressure is utilised in addition

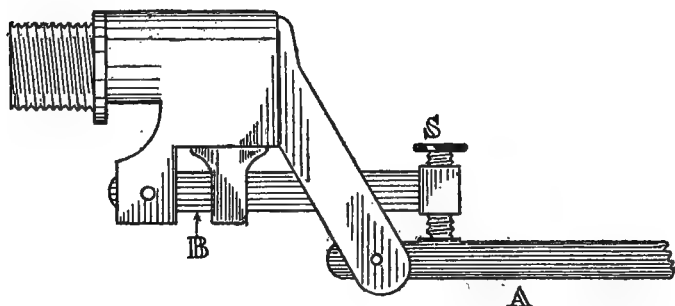


FIG. 196.—The "Hiorlo" ball-cock with compounded lever.

to the float and lever for closing the valve. At the upper part of Fig. 197 a cup-leather C is provided to make the valve water-tight at that point. The pressure of the water is exerted both on the cup-leather C and the valve V, and as their surfaces in the case shown are equal, the total pressure acting upon each surface when the valve is closed is also equal; under these conditions equilibrium is only destroyed by the weight of the ball and lever when the water level begins to sink.

For high-pressure services, cocks like Fig. 197 are not suitable, as they are liable to produce more or less concussion when nearly closed. A drawback associated with ball-cocks which have cup-leathers is their liability to leakage should the cup-leathers get hard and dry through the turning off of water for prolonged periods.

Of the ball-cocks shown, it will be noticed that only in Fig. 197 does the water pressure play any part in closing them, but on the contrary the pressure of the water in Figs. 194 to 196 is always acting to open them. Ball-cocks are, however, made which close with the water pressure, but these are often troublesome for high-pressure services unless a special form of construction is introduced to prevent concussion.

Taps of the *second class* may be subdivided into screw-down and plug forms. Of the screw-down class there are many kinds, both of bib and stop-cocks, but the main principle is common to all.

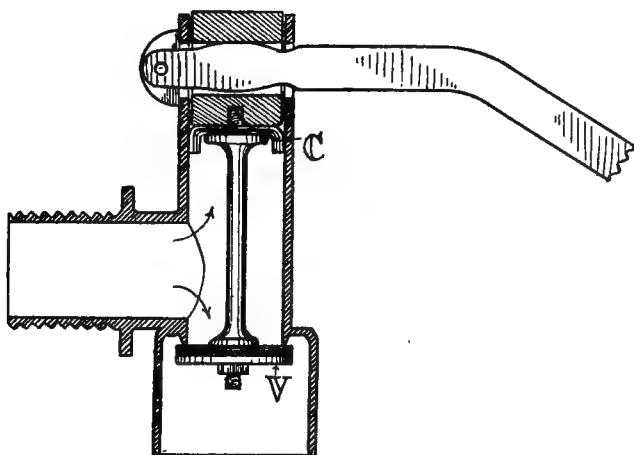


FIG. 197.—Equilibrium ball-cock.

A section through a bib tap is shown in Fig. 198. In a good class of tap the seating should be wide and a little raised in order to form a good bearing for the valve; the screw part of the tap at its lower point should be enlarged as at E, so as to distribute pressure over the greater portion of the loose valve when closing the tap. For a tap to be durable it requires to be strongly made, and especially where high pressures are concerned. A better method of testing water fittings to that frequently adopted by Water Companies is desirable, as many of the jerry made fittings which are put upon the market, although capable of withstanding a pressure

test when they are new, fail after being in use for a comparatively short time.

For water fittings hard brass is a suitable alloy where water contains temporary hardness, but for soft acid waters gun-metal fittings should be used.

A clear-way screw-down cock, Fig. 199, is very suitable for low pressures, as it possesses no loose valve which is liable to stick. It is also suitable for high pressure services.

Plug taps, Fig. 200, are often used for both bib and stop-

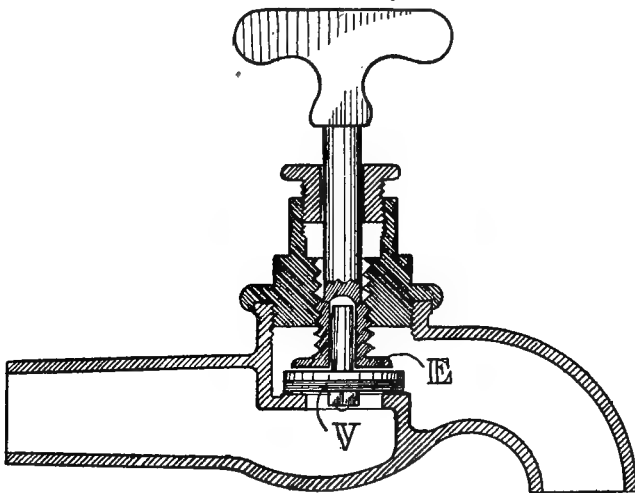


FIG. 198.—High-pressure screw-down cock.

taps where the water pressure is low, as well as for underground stop-cocks on high-pressure services. Plug taps are very suitable for joining directly with cisterns to control the smaller draw-off pipes. These taps are liable to stick when not in regular use, although this can be avoided to a great extent by properly greasing them when they are fixed; moreover, when plug taps are in accessible positions there is very little difficulty in loosening the plugs which may have temporarily become fast.

Bib taps of the plug type, when under a more or less considerable head of water, subject pipes and fittings to

unnecessary strain, when closed too quickly. Plug taps when in constant use work loose, and by suddenly arresting the flow

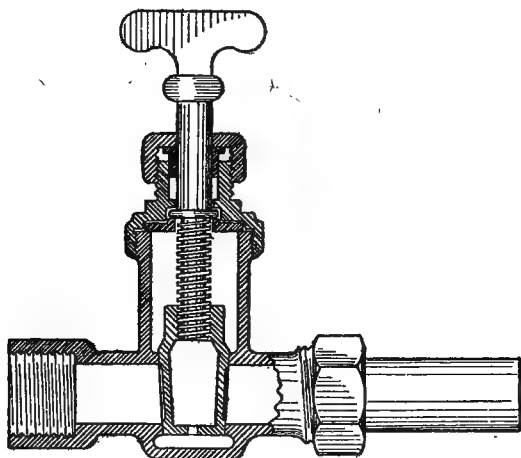


FIG. 199.—Fullway high-pressure screw-down valve.

of water the pressure due to shock is often considerable, and may rise to many times that which is due to the statical head of water.

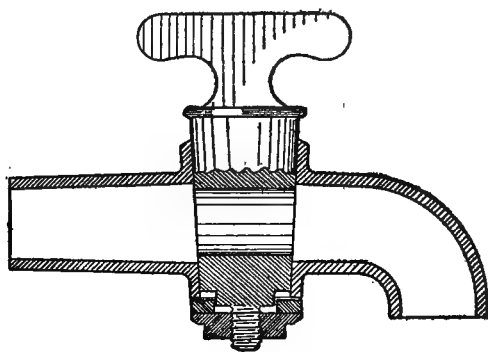


FIG. 200.—Plug cock.

The quick closing of plug bib taps has often been responsible for damaged pipes; sudden shocks are far more detrimental than a constant strain due to high pressure. When a quick-closing tap is fixed to a pipe, the part where the

greatest pressure due to concussion occurs is near the end of the pipe. Bends in pipes influence the result, but as a rule the pressure at different parts of a pipe due to any specific

shock diminishes rapidly from the end. With regard to the intensity of pressure due to shock, that will depend upon the normal pressure of water at the point under consideration, the pressure during the period when withdrawing water, and the rate at which the tap is closed.

Screw-down taps are largely adopted in buildings, as these can be easily repaired, and as they are slowly closed concussion is reduced to a minimum.

A certain amount of care is essential when fixing plug taps. Many plumbers when soldering a plug tap to a lead pipe first remove the plug from the body of the tap, in order to more quickly get up the "heat" for wiping the joint; when the work is complete, and the water is turned on, it is often found that the tap leaks, and to remedy the defect "grinding in" may be necessary. Had the plug been left in the tap during the jointing process it is very probable that the leakage referred to would not have occurred. The reason for this assumption is, that as the temperature of the whole mass of metal would be raised, the rate of expansion would be practically uniform, and upon cooling the rate of contraction would also be even for the whole mass. On the other hand, where the body of a tap has been raised and cooled through a big range of temperature, and the plug has not been subjected to a like action, it is quite feasible for the ground surfaces to be affected owing to the rate of contraction not being quite equal to the rate of expansion. The view-point as indicated above, however, applies more particularly to the cheaper class of taps, many of which are deficient in substance, whilst the quality of the alloy may also be open to suspicion.

Spring taps, which come within the range of the *third order*, may be subdivided into quick and slow-closing types. Quick-action spring taps cause a great amount of concussion, and, like plug taps, are not suitable for draw-off taps on high-pressure services. The primary object of self-closing taps is to reduce waste of water, but in practice more water is frequently wasted by their use than with any other form of tap, owing to their being often out of repair.

A quick-closing spring tap is given in Fig. 201. It will be noticed that the valve V opens against the water pressure,

and therefore the latter is available, in addition to the spring S, for closing the tap. The combined forces of course require to be overcome to open the tap. This form of cock, however, will produce water-hammer in pipes when the press-knob is released, owing to the sudden closing of the tap; where the water pressure is moderately high the valve will recoil from its seating, and a number of successive shocks may occur before the tap is properly closed.

To render a self-closing tap non-concussive its rate of

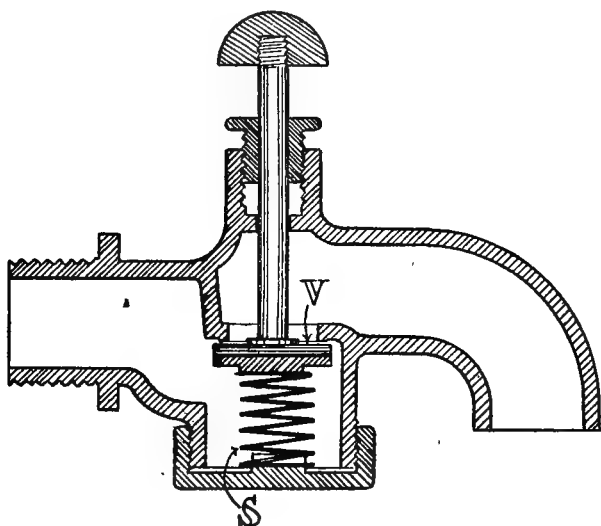


FIG. 201.—Defective form of self-closing tap.

closing requires to be regulated. In Fig. 202 a slow-closing and non-concussive tap is shown by Glenfield & Kennedy Ltd., and contains the following features. Under normal conditions, when the water is on under pressure, the force it exerts on both the under and upper surfaces of the piston P are equal, and the valve *x* is pressed upwards by the water pressure beneath it as well as by the force of the spring. At the under side of piston P a small valve *y* is provided, which is opened by means of a thin spindle which passes through the tubular rod R to the press-knob at the top of the tap. The use of the small valve enables the tap to be

the more easily opened, as the resistance offered by the water to the opening of the valve is directly proportional to its sectional area. For example, if the diameter of a valve is $\frac{3}{4}$ of an inch, and that of another $\frac{2}{3}$ of an inch, the force to open the former would be four times greater than that required to open the smaller valve.

When force is applied on the press-knob the small valve *y* is first opened; this releases the internal pressure in cylinder *C*, by allowing the water to escape through the

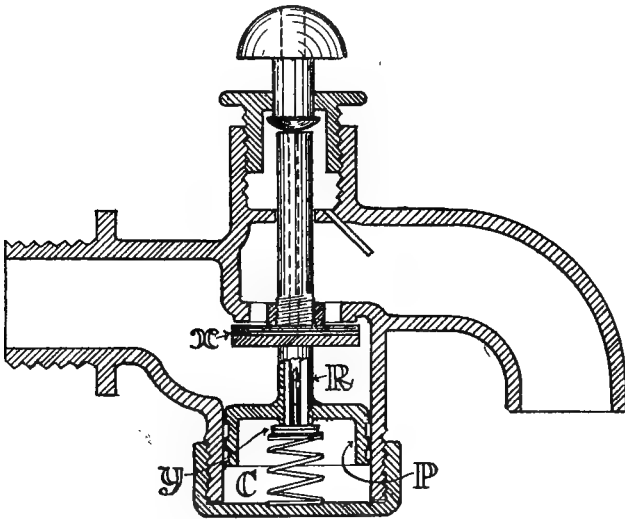


FIG. 202.—Glenfield and Kennedy's non-convulsive self-closing tap.

hollow rod *R* to the outlet of the tap. The differential pressure thus produced on the upper and under surfaces of piston *P* allows the larger valve *x* to be readily opened, when the water freely escapes. To enable the valve *x* to be slowly closed the water is slowly admitted into *C*, either through a small orifice at the top of the piston or by leakage at its sides; upon the press-knob being released the small valve *y* is immediately closed, and as water gradually exerts pressure on the under side of piston *P* the valve begins to close. The sudden closing of *x* is prevented by the downward

force of the water on the top of the piston, and by delaying the equalising of the pressure on both sides of the piston through a given interval of time.

Slow-action, self-closing taps which are similar in principle to Fig. 202 may be used for either low or high-pressure services, but the strength of the springs should be adjusted according to the intensity of the pressure. For low pressures a moderately strong spring is essential to overcome the resistance offered by the piston P, whilst for high pressures a much weaker spring is desirable, as frictional resistance is of less importance. A strong spring has the effect, of course, of making the tap more difficult to open.

Water-Hammer and Other Noises in Pipes.—In describing the different forms of taps, reference has been made to those which are liable to produce shock, and by water-hammer is understood the sharp rapping sounds which are due to shock. Other noises occur in water pipes, such as buzzing sounds, but these differ from water-hammer, as the latter is accompanied by increased pressure, whilst the former are simply due to water flowing with a high velocity through an irregular or contracted orifice, and are not accompanied with any excess of the normal pressure.

A buzzing sound may be produced when a screw-down tap is nearly closed, and where the valve is rather loose or does not close evenly on its seat; if water has greater freedom to flow under one side more so than another, a rotary action is imparted to the loose valve, and thus the buzzing begins.

Whistling sounds are occasionally produced by ball-cocks when nearly closed, but where these sounds are objectionable ball-cocks should be used which have submerged outlets.

The rattling or clicking sounds which are produced by automatic and semi-automatic taps are a form of water-hammer, but shock of much less intensity accompanies these when compared with that of a pronounced water-hammer.

To remedy a case of water-hammer its cause should first be ascertained. If a certain type of ball-cock is responsible for it, it may be necessary to change the cock for another type. Should quick-closing bib taps be the cause of water-hammer, then, if practicable, they should be replaced with the

screw-down type ; but if for some reason quick-closing taps must remain, the only alternative is to provide some form of cushion on which the shock may be absorbed or relieved. For this purpose air-vessels are the most satisfactory fittings, provided that the air-cushion is maintained.

Air-vessels should be fixed to the pipes where the

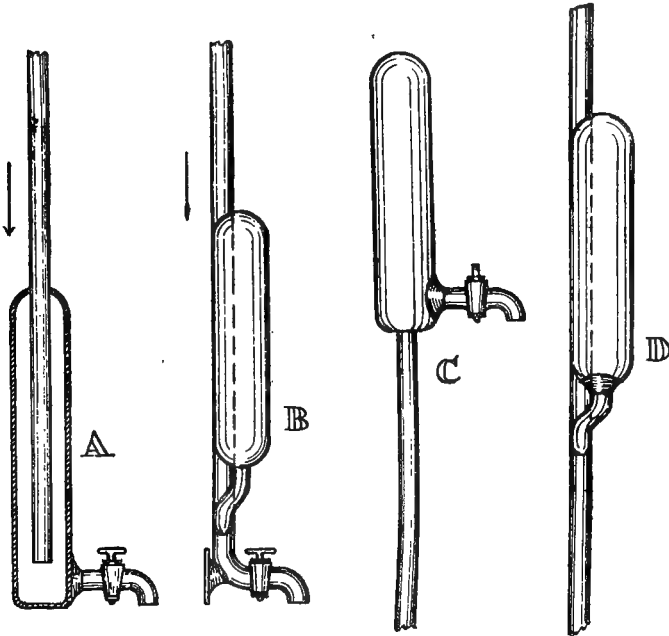


FIG. 203.

Air-vessels for water pipes.

FIG. 204.

maximum pressure due to concussion occurs ; they must be of sufficient strength and of ample size.

In Fig. 203 two different methods of fixing air-vessels are given where the flow of water is in a downward direction. The air-vessels are fixed close to the source of concussion, the plug tap in A being joined directly with the air-vessel, whilst in B the air-vessel is connected with the side of the pipe immediately above the tap. At C, Fig. 204, an air-vessel is fixed at the head of the pipe, and at D of the same figure

at some intermediate point. If the air-vessel in D is some distance removed from the cause of water-hammer, it will not effectively cure it although it will diminish the shock to a more or less extent.

To provide an effective cushion of air, air-vessels should not be less in diameter than twice that of the pipes to which they are to be attached, and not less than 18 inches in length.

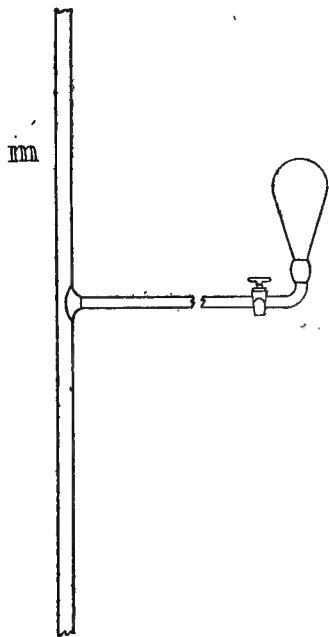


FIG. 205.—Air-vessels for water pipes.

Instead of using a special form of air-vessel, the end of a pipe is sometimes bent upwards so as to serve the same purpose, but in the latter case the capacity of the pipe is too small to be effective.

It will be occasionally found that when a quick-closing tap is fixed on a branch, as in Fig. 205, a ball tap at a higher point, and which is connected with the same service pipe, is caused to vibrate and to produce sharp clicking sounds when the bib tap is rapidly closed. The concussion in the branch may be relieved by an air-vessel as shown, but as the pressure in pipe M rapidly falls when the bib tap is opened, there is also a momentary gain of pressure in the same pipe when the

tap is quickly closed. The fixing of an air-vessel, however, in the immediate neighbourhood of a ball-cock may tend to accelerate water-hammer rather than to prevent it. For an air-vessel to be effective in one case and not in another may at first appear anomalous, but when the difference in construction of ball and quick-closing taps is taken into account the anomaly disappears. There is no common cure for all cases of water-hammer, and each case requires to be considered on its own merits.

So violent sometimes are the shocks produced by water-hammer that the sound is transmitted long distances. When several houses are supplied by one common service pipe, it is no unusual thing for water-hammer in one house to be heard in all the others.

Under certain conditions a quick-action tap may produce little or no concussion, but this largely depends upon the size of the pipe and the position where the tap is joined. Thus, if a plug stop-cock in connection with a service pipe is connected directly with, or close to a water main, the quick closing of the tap would not greatly affect either the pressure at the tap or that in the water main. The reason for this is rendered clear when the short distance from the tap to the main, and the relative velocity of the water in the service pipe and that in the main, are taken into account.

Suppose, for example, a tapping main is 6 inches diameter, and the orifice in the plug of a tap 1 inch diameter, and that the tap is joined directly to the main. Taking the velocity of the water through the tap at 9 feet per second, the velocity in the 6-inch main to yield this would be $\frac{1^2 \times 9}{6^2} = \frac{1}{4}$ ft. or 3 inches per second. Thus the concussion which would occur in the main by suddenly arresting such a low velocity would not be of much account. It is very different, however, in the case of long pipes, where the cocks are of the same size, for then the velocity of flow through each is equal, and the greater the velocity the greater the shock when the flow is abruptly stopped.

It should be distinctly understood that when air-vessels are used in water service pipes, their efficacy for preventing or reducing the effects of water-hammer is entirely dependent upon their air-cushions being maintained. Unless air is frequently added to air-vessels they are soon rendered useless for their purposes owing to its being absorbed by the water.

CHAPTER XI

APPLIANCES FOR RAISING WATER

HYDRAULIC rams and pumps are largely used for raising water from a low to a higher elevation, but the use of the former is limited when compared with the latter appliances.

Pumps take various forms, but they may be classified as follows:—

1. Single action lift pumps.
2. Double action lift pumps.
3. Lift and force pumps.
4. Plunger or force pumps.
5. Air-lift pumps.
6. Centrifugal pumps.

Those indicated by 3 and 4 may be either single or double acting, and they may also be arranged to work with one, two, or three barrels. Those in 5 and 6 scarcely come within the scope of this work, and in consequence they will only be briefly dealt with.

Lift Pumps.—When an ordinary lift pump is used for raising water from a well, the height to which water can be raised is limited by atmospheric pressure. The pressure of the atmosphere varies with altitude and with different weather conditions, but taking the normal atmospheric pressure at sea level to be $14\frac{3}{4}$ lb. per sq. inch, this is equivalent to the pressure exerted by a column of water which is 34 feet in height. As a margin of power must be on the side of the atmosphere to overcome internal resistances of a pump, the maximum height to which water can be raised by a lift pump is about 28 to 30 feet. This height should be measured from the lowest water level to the top of the bucket or plunger when the pump handle is down.

Iron lift pumps may take the form shown in Fig 206. They may be fixed to a wall or wooden plank, or be made taller than the one shown, and supported by bolting them to stone flags.

The bucket B in Fig. 206 is made water-tight at its sides with a cup-leather, and a valve *x* is arranged to open when the bucket is descending and to close when being raised. The valve V holds up the water in the pump, and prevents its returning into the suction pipe when the bucket is descending. The action of the pump is as follows: When the bucket descends, the upper valve opens, and water escapes above it; upon the bucket being raised, the water above it is displaced through the outlet, and at the same time atmospheric pressure forces up the water through the suction pipe to fill the space through which the bucket has moved.

The term "suction" pipe is often misleading, as it indicates that the water is raised by suction instead of being due to displacement by atmospheric pressure.

When an iron pump is used the working part of the barrel should be fitted with a thin gun-metal lining, in order to preserve the cup-leather and to keep the pump in good order.

Suction Pipes.—For economical considerations, and also for convenience, suction pipes are usually smaller than the

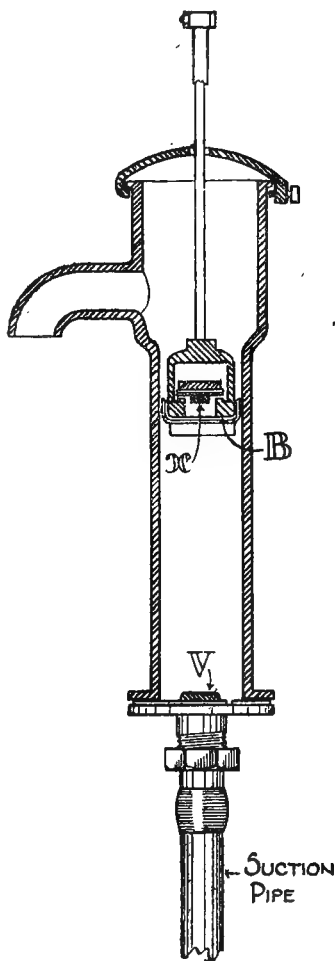


FIG. 206.—Lift pump.

barrels of the pumps. The effect of reducing the sizes of suction pipes is to increase frictional resistances, as the water has to flow through them at a greater velocity than through the barrels of the pumps. If, for example, a pump is of 4 inches diameter, and its suction pipe of 2 inches diameter, the velocity through the latter would be 4 times that through the barrel of the pump.

Under ordinary circumstances, where a suction pipe is not very long, and where a pump is worked at a slow rate, a suction pipe whose diameter is half that of the pump will give satisfaction. On the other hand, should a suction pipe be very long, it should be increased by one size, and the area of the retaining valve should also be as large as practicable. Suction pipes when subject to corrosion should also have larger bores.

Frequently when a suction pipe is long, a pump is difficult to work. The cause of this may be due to the suction pipe being too small, or to other restricted water passages, such as the lower end of the pipe being partially choked. Should the flow of water through a suction pipe be unduly retarded, the action of the bucket will resemble that of a spring when in tension. If the flow to a pump is not as free as the rate of displacement from it, a partial vacuum is created, and the bucket will endeavour to fly back to restore equilibrium when the handle is quickly released.

The greatest amount of power when pumping, is required at the commencement of the stroke, as the inertia of the water requires to be overcome before the latter can be put into motion. With a single action pump like Fig. 206 the power to move the piston will vary with the upward and the downward strokes, as well as at the commencement of pumping.

The energy required to put water in motion in long suction pipes may be much reduced by fixing air-vessels immediately beneath the retaining valves, as in Fig. 207. In form, the air-vessel for a suction pipe may be similar to that of an ordinary air-vessel, but instead of its contained air being in a state of compression it is more or less extended. If it is assumed that a pump is being worked which has an air-vessel attached, as in Fig. 207, then at the beginning of each stroke the rising water will compress the confined air to a certain extent, but at the

completion of the stroke the column of water in the suction pipe will tend to sink a little, and so extend the air in the vessel. This has the effect of providing a force with a spring-like action which pulls against the water, and so makes it ready to be put into motion when commencing to work the pump.

Occasionally a non-return valve is fixed in a suction pipe immediately above the water-line of a well or tank from which the water is pumped. Such a valve is useful in certain cases,

where the retaining valve of a pump cannot be depended upon, or where two pumps in different situations are connected with one suction pipe. A non-return valve, however, should not be used for a suction pipe which has an air-vessel attached, or the latter would be rendered useless, and in consequence the pump would be more difficult to work. Suction pipes should be arranged so that air cannot lodge in them, and this can be done by making them rise to the pumps for the whole of their length.

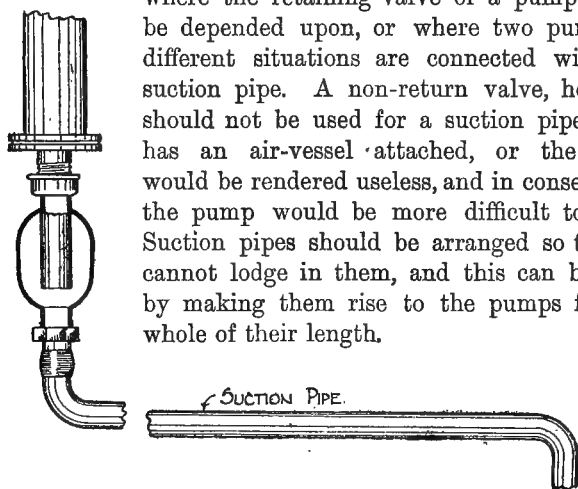


FIG. 207.—Suction pipe with air-vessel attached.

Pumps for Deep Wells.—Where the vertical distance between the lowest water level in a well and the top of a pump bucket exceeds say 30 feet, the working part of the pump will require to be fixed in the well in order that water may be raised. For a well of great depth the suction pipe should be made as short as practicable, or, in other words, the working part of the pump should not as a rule be more than about 15 feet above the normal water-line, when the lowest water level is only about 5 feet less. In certain wells, where the water level is lowered by pumping to a considerable extent, it may be necessary for the working part of the barrel to be submerged when the highest water-line is reached.

When a single action pump is used for raising water from a well of moderate depth, and where hand power only is available, the size of a pump requires to be limited.

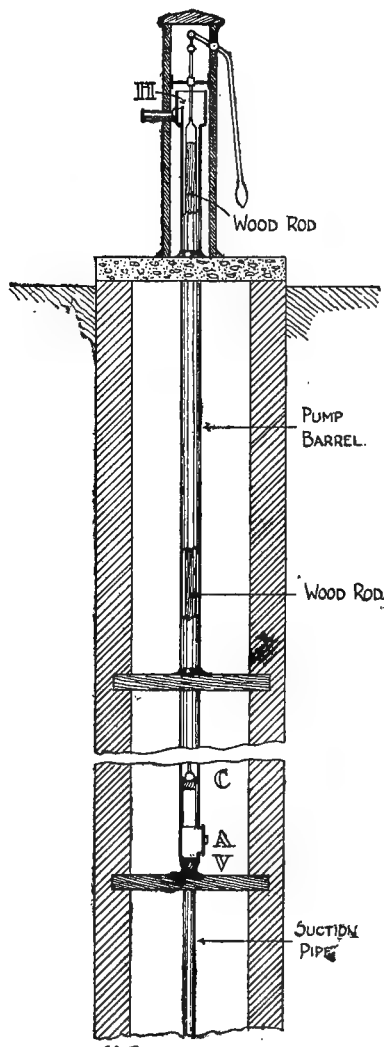


FIG. 208.—Lead pump for deep wells.

A type of pump which has often been used in country districts for wells which vary in depth from 20 to 80 feet is given in Fig. 208. The barrel and suction pipe are of lead, the former being 4 inches and the latter 2 inches diameter. To the upper end of the pump barrel a lead head is joined, and in turn a lead spout is fixed to the head. It will be observed that the barrel portion stands up inside the head at H in front of the spout, whilst towards the back of the head it is cut away. This arrangement prevents the pump being damaged by pieces of stick, or by small stones being passed through the spout and into the barrel by children; at the same time the water can freely escape from the back.

The pump rod, which is generally of wood, passes through the barrel, and to its upper end the guide arrangement is attached,

whilst to the lower end the iron-work of the bucket is fixed. The wood rods are made in convenient lengths for handling,

and they are spliced together as they are passed into the pump. The joints of the rods require to be well formed, both to prevent failure at these points and to provide for their being readily taken apart. A copper cylinder C should be fixed immediately above the access opening A, in order to provide a suitable place in which the bucket can work. A non-return valve is provided at V, and this can be renewed or repaired by means of the opening at A.

There is no difficulty in balancing a handworked pump like Fig. 208, as the wood rods are buoyed up with the water and the pump is double acting in principle; that is, it will raise water with both its upward and its downward strokes. A casual glance at the pump may not reveal this, but when it is considered that at each downward stroke a volume of water must be displaced by the rod, then obviously the upward stroke must displace that much less. By making the diameter of the pump rod equal in area to half that of the barrel, the volume of water due to the full length of the stroke may be equally divided and displaced by the upward and downward motion of the rod.

A pump similar to Fig. 208 can be worked with a given power which would be totally inadequate to operate one with iron rods, provided the conditions with regard to size, and the height through which water requires to be raised, are equal.

For supporting lead pumps oak bearers are often employed; these are fixed on each side of the pump barrel, and pieces of oak board which have been cut to fit around the barrel are nailed across the bearers. It is usual to join two lengths of barrel at each point of support, and lead flanges are used to provide the necessary bearing. A convenient length for lead pump barrel is 8 feet, and such a length can be properly supported in the manner described.

In this class of work it is usual to tin the prepared pipe ends, either with a Swedish torch or with a soldering bolt, and to fix the opened ends downward. The latter precaution is necessary to guard against solder entering the barrel when making the joints. To protect the upper part of the pump it should be cased in, and a suitable insulating material should also be used when a pump is fixed in an exposed situation.

When a 4-inch pump is used to raise water through a great height, long handles are essential to give the necessary leverage, but at the same time long levers limit the length of the stroke and are cumbersome to use.

Double action pumps take different forms, but when they are arranged to deliver double the volume of water of a single action type through a given height, then the power to work them requires to be increased. Such pumps as a rule are operated by some form of motive power. The form shown, however, in Fig. 208 will only raise the same volume as a single action pump, but it possesses the advantage of dividing the power to raise the water between the upward and the downward strokes.

Lead pumps, of course, are not suitable for raising water for dietetic purposes if the water has any corrosive action on this metal, but as a rule, well waters contain temporary hardness and have no action on lead.

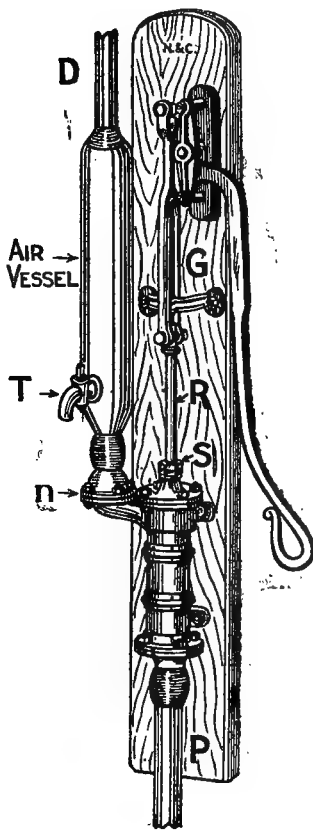


FIG. 209.—Lift and force pump
by Nicholls and Clarke.

Lift and Force Pumps.—Fig. 209 gives a lift and force pump, and this type is commonly employed for raising water to the higher parts of buildings when the water supply is derived from a well. The pump is fixed to an oak plank, which in turn is secured to a wall or other structure. As already stated, when

a pump is fixed above ground level the vertical distance between it and the water in a well is limited by atmospheric pressure; so far, however, as the height to which water above the pump can be raised, this is controlled by the mechanical advantage of the lever, and by the force a person can bring to

bear upon the handle when working it continuously for a given time.

In a lift and force pump the water is put in motion both in the suction pipe P and in the delivery pipe D with the upward motion of the bucket; the chief resistances to the downward stroke are those due to the stuffing box S, and the cup-leather of the bucket. The guide G keeps the bucket rod R in a vertical position, which is essential when sliding through a water-tight stuffing box. The delivery pipe D, like the suction pipe, should not be less than half the diameter of the pump, or the latter will be difficult to work. Where a delivery pipe is long, and where water is raised through moderate heights, an air-vessel should be attached immediately above the non-return valve *n*. An air-vessel has the effect of diminishing shock at the commencement of the stroke, and of reducing the power to put the water in the delivery pipe in motion. An air-vessel of liberal size should be used, in order that a large portion of the water at each stroke may enter it.

The confined air in a vessel on a delivery main acts like a spring in compression, its force per sq. inch being equal to that of the column of water which presses upon the air-vessel. A non-return valve *n* is essential for a lift and force pump, to prevent the water in the delivery main from returning into the pump upon the downward stroke of the bucket.

At T, Fig. 209, water can be obtained directly from a well, and the tap also admits of the delivery main being emptied.

In Fig. 210 a plunger or force pump is given. With this form of pump the water is displaced from the barrel with the downward stroke of the piston, and the delivery pipe joins at the bottom of the pump as in the figure. So far as the operating of a pump is concerned, the plunger type possesses an advantage over the lift and force form, in that the energy in the case of the former is divided between the upward and the downward strokes, whilst with the latter practically the whole of the burden comes upon the upward stroke.

The bucket of a plunger pump is often formed with double cup-leathers, and the non-return valve and air-vessel may be arranged as shown. A draw-off cock should be

provided just above the non-return valve, in order that the air-vessel may have its air supply renewed when this is found necessary.

When lift and force pumps are used for raising water from deep wells, double barrelled types, Fig. 211, are frequently adopted. When pumps have double barrels the rods balance each other, as one rod is arranged to ascend

whilst the other descends; moreover, double barrelled pumps can be of smaller diameter when compared with single forms, and the power necessary to work them can be the better utilised.

Pumps for deep wells are generally provided with wheel and cranks in lieu of levers, as the former admit of the better utilisation of the energy when working them, and they can be operated from two sides at the same time by adding the extra handle H, as in Fig. 211. The wheel W should be about 4 feet diameter, and be of moderate weight so as to serve the purpose of a flywheel.

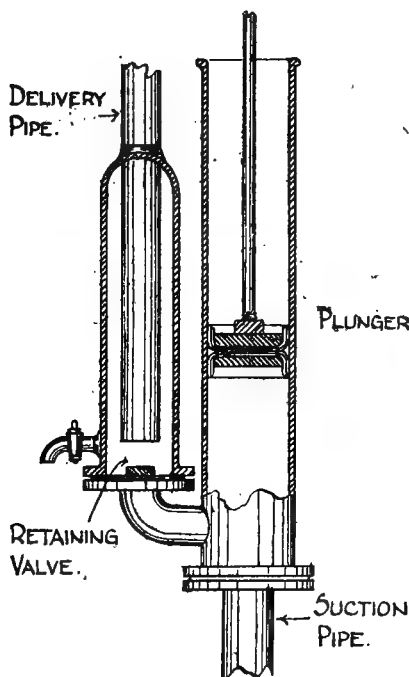


FIG. 210.—Plunger type of force pump.

Double barrelled pumps do not require such large air-vessels as single pumps, as the delivery of water is more nearly regular. It will be observed in Fig. 211 that twice the length of the crank determines the length of the stroke, and that with an ungeared pump a stroke is completed at each revolution of the wheel.

In some cases, where water requires to be raised through more or less considerable height, and where only hand power

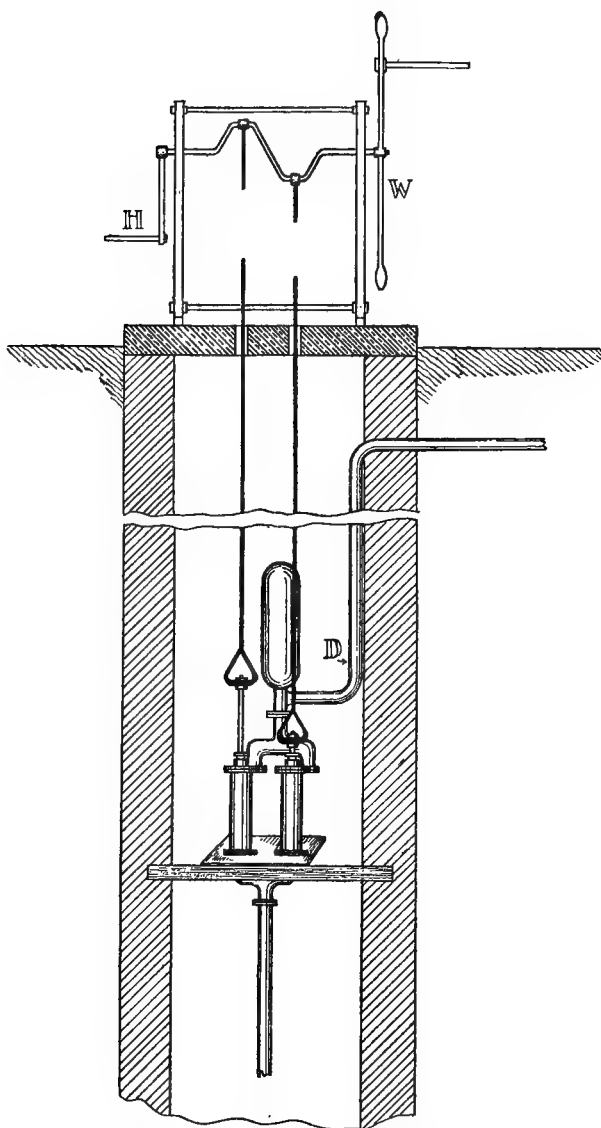


FIG. 211.—Double barrelled lift and force pump.

is available, gearing is resorted to. The effect of gearing is to reduce the working power by spreading the effort over a longer period; in other words, for each complete stroke of a pump the wheel will make two or more revolutions, according to the ratio of the gearing adopted.

For farms and other places, where horse power is available, that source of energy may be utilised for raising water by providing suitable gearing.

If it is necessary to raise large volumes of water through a great height in a limited time, some form of motive power becomes necessary.

In country districts windmills or wind engines can often be utilised for raising large volumes of water at a comparatively small cost, but for these appliances to be effective they require to be fixed in exposed situations. Wind engines are arranged to automatically adjust themselves to suit either moderate or high velocities of wind, and also when blowing from any direction.

The size of a mill is governed by the amount of work to be done, and by its relative position to surrounding objects which may obstruct the wind. For example, a 10-foot mill in an exposed situation may be equal in power to a 16-foot mill which is located in a somewhat sheltered position. Roughly speaking the power of a wind engine varies according to the square of its diameter, when other conditions are equal.

It is occasionally found that after a pump has been installed it gets more difficult to work, but the cause as a rule is not difficult to discover. For example, if a lift and force pump requires more energy to work it than it should do, the first thing to do is to ascertain on which side the pump the cause has been introduced. This can be readily done by opening the draw-off tap so as to empty the delivery main, when a smart stroke or two will indicate whether the bucket works too tightly in the barrel, or whether the suction pipe is partially choked. Should the suction side of the pump be found satisfactory, then it is obvious that the fault is on the delivery side. Under the latter circumstances it is possible that the air-vessel has been water-logged, or if this is not the cause, then the delivery main should be

examined to see if it has been flattened at any point; the non-return valve at the foot of the delivery pipe should also receive attention.

Centrifugal Pumps.—The ordinary type of centrifugal pump is of simple construction, the water being raised by an impeller which is keyed to a shaft, and which revolves at a high velocity inside a metal casing. The impeller usually contains six vanes, and the water enters at the centre and leaves at the tips of the vanes. To utilise as far as practicable the energy due to the revolving mass, the space into which the water is delivered upon leaving the impeller is gradually enlarged towards the outlet of the pump. This form of construction has the effect of reducing the velocity of the water as it approaches the outlet, and of converting its kinetic energy into pressure. A low head centrifugal pump delivers a constant stream, and is very suitable for raising large volumes of water through a comparatively small height. The efficiency of this type diminishes as the height of the lift is increased.

High Lift Centrifugal Pumps.—During recent years great improvements have been effected in the construction of centrifugal pumps, and the limited heights to which water could be economically raised by earlier types has been largely overcome by constructing these pumps in compound form. Instead of one chamber, two or more are provided, each having its own impeller, which is keyed to one common shaft. After water is delivered from the first impeller, it passes into the second chamber, and thence through the rising main or subsequent chambers.

Single impeller pumps of special design will also raise water through a height of over 150 feet.

Air-Lift Pumps.—These can only be used for wells which have a considerable depth of water, and under the best conditions air-lift pumps only have a small mechanical efficiency. For this type of pump, air is delivered under a certain pressure through a nozzle at the bottom of the rising main, the lower end of which must be submerged to a greater depth than the height through which water is to be raised. An air compressing plant is essential to operate these pumps

and when sufficient air at the necessary pressure is delivered through the submerged nozzle, the downward pressure of the water in the well is sufficient to overcome that of the air and water in the rising main, when the water is caused to rise and escape at the outlet. The air and water do not mix in the rising main but form themselves into alternate bands or short columns.

Efficiency of Pumps.—If a pump were perfect it would raise in a given time a volume of water equal to the space traversed by the plunger, multiplied by the number of strokes in the time under consideration. In practice, however, less water than the above would be raised on account of a certain volume slipping back during the closing of the valves and by leakage at the sides of a bucket. If a pump is in good condition it may have an efficiency as high as 99 per cent., and on the other hand its efficiency may fall to, or below, 50 per cent. when in a poor or indifferent state of repair. Lever pumps as a rule are not so efficient as wheel pumps, as the latter have a more nearly uniform stroke, whilst the former are more jerky in action and are not always given a complete stroke.

For the purpose of calculation lever pumps will be assumed to have an efficiency of 85 per cent. This is a fair basis to work upon, and a standard which any good form of pump should satisfy when not worked exactly under ideal conditions.

Lever Pump Formula.—The lifting capacity of an ordinary lever pump upon the basis stated can be obtained by the following formula :—

$$G = \frac{d^2 \times l \times n \times t}{416} \quad . \quad . \quad . \quad . \quad . \quad . \quad (27)$$

Where G = volume of water raised in gallons.

„ l = length of stroke in inches.

„ d = diameter of pump in inches.

„ n = number of strokes per minute.

„ t = time of pumping in minutes.

Example 11.—An ordinary lift pump is $3\frac{1}{2}$ inches diameter, how many gallons of water would it raise in half an hour with a 9-inch stroke, and when worked at 20 strokes per minute?

By Formula 27, $G = \frac{d^2 \times l \times n \times t}{416}$;

Substituting values, $G = \frac{(3\frac{1}{2})^2 \times 9 \times 20 \times 30}{416} = \frac{33075}{208}$,

$\therefore G = 159$ gallons, which are raised in half an hour.

Assuming the diameter of a lever pump is required for raising a given volume of water in a certain time. By transposing Formula 27 we have—

$$d = \sqrt{\frac{G \times 416}{l \times n \times t}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (28)$$

Example 12.—Determine the diameter of a lever pump which will raise 65 gallons in 20 minutes, if it has a 7-inch stroke and when worked at the rate of 22 strokes per minute.

$$\text{Formula 28 gives } d = \sqrt{\frac{G \times 416}{l \times n \times t}}$$

Substituting the values given, $d = \sqrt{\frac{65 \times 416}{7 \times 22 \times 20}}$,

$$d = \sqrt{8.78};$$

$\therefore d = 2.96$, or say 3 inches diameter.

The power which is necessary for operating a lever handled pump can be obtained, when the length of each part of the lever from the fulcrum, and the resistances to be overcome, are known. In Fig. 212 an ordinary pump handle is shown which represents a lever of the first order.

By the following general formulæ any one of the four values which are represented by the symbols can be found when the other three are given. In pump calculations the actual weight of the handle is not taken into account, as the bucket nullifies to a great extent the advantage derived by the extra weight of the longer arm.

$$P = \frac{F \times x}{y} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (29)$$

$$y = \frac{F \times x}{P} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (30)$$

overcome when raising water by an ordinary lift pump Fig. 206, may be obtained by the following formula :—

$$P = \frac{d^2 \times 9 \times h}{25} \quad . \quad . \quad . \quad . \quad . \quad . \quad (33)$$

Where P = total resistance in lbs. to be overcome.

„ d = diameter of pump in inches.

„ h = height in feet through which water is raised.

When the right side of the equation in 33 takes the place of P in Formulæ 31 and 32, we obtain the following:—

$$F = \frac{d^2 \times 9 \times h \times y}{25 \times x} \quad . \quad . \quad . \quad . \quad (34)$$

$$x = \frac{d^2 \times 9 \times h \times y}{25 \times F} \quad (35)$$

and by transposition, $d = \sqrt{\frac{25 \times x \times F}{9 \times h \times y}}$ (36)

When an ordinary lift pump is used for raising water for supplying a house, its diameter as a rule does not exceed 4 inches. Where the short and long parts of a lever are in the ratio of 1 to 6 a 4-inch pump should not be difficult to work.

Example 14.—If a $\frac{1}{4}$ -inch lift pump raises water through a height of 24 feet, and the short and long sides of lever are 6 inches and 36 inches respectively, determine the effort which must be applied at the end of the lever.

By Formula 34, $F = \frac{d^2 \times 9 \times h \times y}{25 \times x}$.

Substituting values given, $F = \frac{4^2 \times 9 \times 24 \times 6}{25 \times 36} = \frac{576}{25}$;

$\therefore F = 23\frac{1}{5}$, or say 23 lb., which must be applied at the end of the lever.

The effort that can be applied by a person is limited, and as a rule this will vary from 18 to 25 lb. when pumping continuously for fairly long periods. The length of a pump handle is also limited, for when a handle is very long it cannot be raised sufficiently high to utilise the full length of its stroke. It is also cumbersome to work.

The diagram Fig. 213 shows the distances through which

the hand travels with handles of varying lengths when the levers are moved through 90° . The vertical distances through which the hand is raised are also given. With a handle 2 feet long it will be seen that the distance through which the hand travels is 3 ft. 1 $\frac{1}{2}$ in., whilst the vertical height is 2 ft. 3 in. For a 4-foot handle the length of the

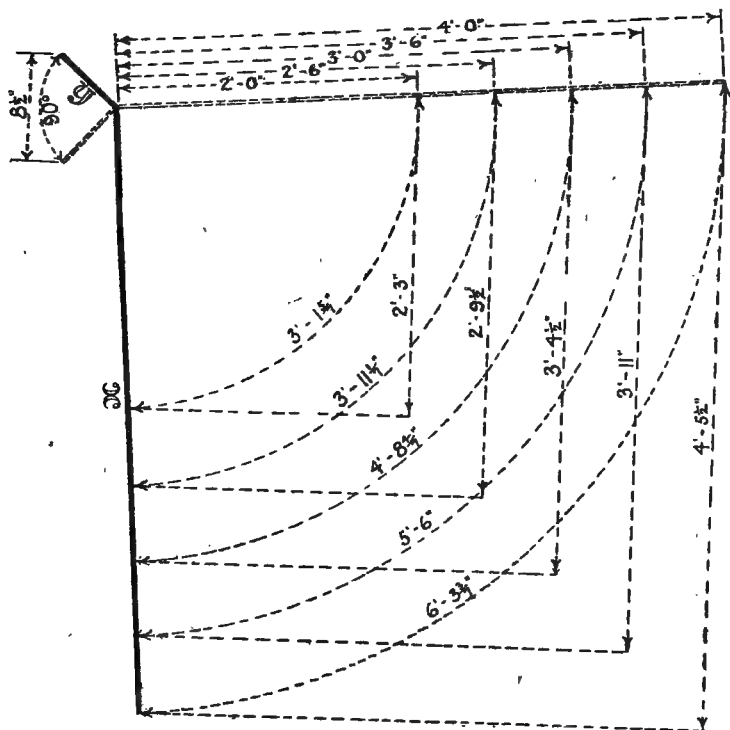


FIG. 213.—Diagram illustrating limiting lengths for pump handles.

arc and the vertical distance are 6 ft. 3 $\frac{3}{4}$ in. and 4 ft. 5 $\frac{1}{2}$ in. respectively. In Fig. 213 the short lever arm is 6 inches, and when this is turned through 90° it gives a stroke of 8 $\frac{1}{2}$ inches. Should the length y be less than 6 inches the stroke would be shorter than shown, unless the handle were moved through a greater number of degrees.

Formulae for Lift-and-Force Pumps.—To find the diameter

of a lift-and-force pump for raising water through more or less considerable height, and where the power and leverage are limited, the following formula can be used:—

$$d = \sqrt{\frac{50 \times x \times F}{19 \times h \times y}} \quad . \quad . \quad . \quad . \quad . \quad . \quad (37)$$

Where d = diameter of pump in inches.

„ x = long side of lever in inches.

„ y = short side of lever in inches.

„ F = force applied on pump handle.

„ h = height through which water is raised.

Example 15.—Determine the diameter of a lift-and-force pump for raising water through a total height of 75 feet, when the short and long parts of lever are 5 inches and 33 inches in length, and when a force of 24 lb. is to be applied at the end of the lever.

$$\text{By Formula 37, } d = \sqrt{\frac{50 \times x \times F}{19 \times h \times y}}$$

$$\text{Substituting values given, } d = \sqrt{\frac{50 \times 33 \times 24}{19 \times 75 \times 5}};$$

$$\therefore d = \underline{2.35 \text{ inches diameter.}}$$

As this is an odd size the nearest stock size would be selected.

Transposing Formula 37, we have—

$$F = \frac{d^2 \times 19 \times h \times y}{50 \times x} \quad . \quad . \quad . \quad . \quad . \quad . \quad (38)$$

Example 16.—Supposing a lift-and-force pump, Fig. 209, is of 3 inches diameter, and is used for raising water through a height of 60 feet; what force must be exerted on the end of the lever when the short and long sides are 5 inches and 32 inches respectively?

$$\text{By Formula 38, } F = \frac{d^2 \times 19 \times h \times y}{50 \times x}$$

$$\text{Substituting values given, } F = \frac{3^2 \times 19 \times 60 \times 5}{50 \times 32} = \frac{513}{16};$$

$$\therefore F = 32\frac{1}{16}, \text{ say } \underline{32 \text{ lb.}}$$

Example 17.—Give the volume of water which would be raised by the pump in the last example in fifteen minutes, if it

has a 7-inch stroke and is worked at the rate of 22 strokes per minute.

$$\text{By Formula 27, } G = \frac{d^2 \times l \times n \times t}{416}.$$

$$\text{Substituting values given, } G = \frac{3^2 \times 7 \times 22 \times 15}{416} = \frac{10395}{208};$$

$$\therefore G = 49.9, \text{ or say } \underline{50 \text{ gallons.}}$$

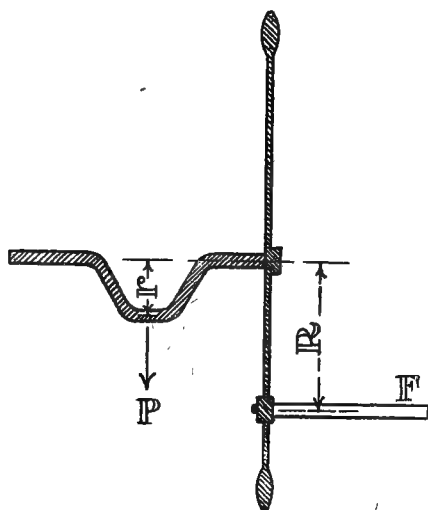


FIG. 214.—Illustrating mechanical advantage of wheel handle.

Wheel-pumps have an advantage over those with lever handles, as the former give a full stroke with each revolution of the crank they better utilise the energy imparted to them, and are less jerky in action.

By the aid of Fig. 214 the mechanical advantage of a wheel will be made clear, besides helping to explain the meaning of the symbols used.

Formulae for Single Action Lift - and - Force Wheel Pumps.—For lift-

and-force pumps like Fig. 211, and where the rods are balanced, the following formula may be used:—

$$F = \frac{d^2 \times 19 \times h \times r}{50 \times R} \quad . \quad . \quad . \quad . \quad . \quad (39)$$

$$d = \sqrt{\frac{F \times 50 \times R}{19 \times h \times r}} \quad . \quad . \quad . \quad . \quad . \quad (40)$$

Where F = force in lbs. applied to handle of wheel.

„ r = radius of crank in inches.

„ R = radius of wheel as in Fig. 214.

„ d = diameter of pumps in inches.

„ h = height through which water is raised.

It will be observed, upon reference to Fig. 214, that the length of the crank r determines the length of the stroke, which is equal to twice that of the crank. For convenience, the radius R of pump wheel is often limited to 14 or 15 inches, but where the resistances to be overcome are large a bigger radius may be adopted, or gearing may be resorted to.

The usual form of gearing is shown in Fig. 215, where the

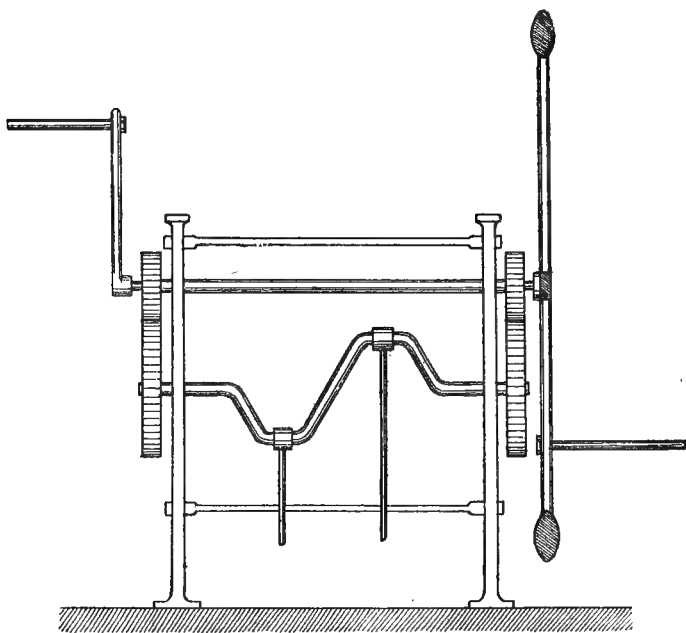


FIG. 215.—Gearing for double barrelled deep well pump.

pump wheel is connected to a shaft on which are small cog wheels, which in turn react on larger cog wheels to which the crank rods are joined. The ratio of the gearing is obtained by counting the number of cogs in each wheel. Thus, if the upper and smaller wheel contains 6 cogs, and the larger or lower wheel 15 cogs, then the gearing is in the ratio of 15 to 6, or $2\frac{1}{2}$ to 1; in other words, $2\frac{1}{2}$ revolutions of the fly wheel are necessary to complete one stroke of the pump. For purposes of calculation the higher number will be expressed

as a ratio of the smaller, and for the case referred to this equals $\frac{1}{2\frac{1}{2}}$.

Formulae for Geared Lift-and-Force Pumps.—

$$F = \frac{d^2 \times 2 \times h \times q \times r}{5 \times R} \quad . \quad . \quad . \quad . \quad . \quad (41)$$

$$\text{and } d = \sqrt{\frac{F \times 5 \times R}{2 \times h \times q \times r}} \quad . \quad . \quad . \quad . \quad . \quad (42)$$

Where q = the ratio of the revolutions made by the wheel to one made by the crank.

The remainder of the notation is as before.

Example 18.—Find the force which must be applied to the handle of a 3-inch diameter lift-and-force wheel-pump, in order to raise water through a height of 120 feet, when the radii of the crank and wheel handle are $4\frac{1}{2}$ and 18 inches respectively.

As the pump in the example is not geared, the force to work it will be found by Formula 39.

$$\text{Where } F = \frac{d^2 \times 19 \times h \times r}{50 \times R}.$$

$$\text{Substituting values given, } F = \frac{3^2 \times 19 \times 120 \times 4\frac{1}{2}}{50 \times 18} = \frac{513}{5};$$

$$\therefore F = \underline{102\frac{3}{5} \text{ lb.}}$$

The working shows that the pump is unsuited for manual labour where only one or two persons could operate it. If it is assumed that two men could be employed to work the pump, each would require to exert about 51 lb. on the wheel handle.

Example 19.—Suppose, now, we desire to find the diameter of a pump which can be worked by one man when exerting a force of 28 lb. on the wheel handle, in order to raise water through a height of 120 feet. Assume the wheel is geared in the ratio of 3 to 1, and that the radii of the crank and the wheel are $4\frac{1}{2}$ inches and 18 inches as before.

$$\text{By Formula 42, } d = \sqrt{\frac{F \times 5 \times R}{2 \times h \times q \times r}}$$

Substituting the values given, $d = \sqrt{\frac{28 \times 5 \times 18}{2 \times 120 \times \frac{1}{2} \times 4\frac{1}{2}}} = \sqrt{7}$;

$\therefore d = 2.64$, or say $2\frac{1}{2}$ inches diameter.

Should the lifting capacity of a geared wheel-pump be required, it may be directly obtained by the following:—

$$G = \frac{d^2 \times r \times n \times t \times q \times B}{190} \quad . \quad . \quad . \quad . \quad (43)$$

Where G = gallons raised.

„ d = diameter of pump in inches.

„ r = radius of crank in inches.

„ n = number of revolutions made by fly wheel per minute.

„ t = time in minutes.

„ q = the ratio of gearing adopted.

„ B = number of pump barrels.

Example 20.—Find the volume of water which should be raised in 35 minutes by a double-barrelled lift-and-force pump of 2 inches diameter, where the fly wheel makes 30 revolutions per minute and where the crank has a radius of $4\frac{1}{2}$ inches. The wheel is also geared in the ratio of $2\frac{1}{2}$ to 1.

$$\text{By Formula 43, } G = \frac{d^2 \times r \times n \times t \times q \times B}{190}.$$

Substituting the values given,

$$G = \frac{2^2 \times 4\frac{1}{2} \times 30 \times 35 \times \frac{1}{2\frac{1}{2}} \times 2}{190} = \frac{1512}{19};$$

$$\therefore G = 79\frac{1}{19}, \text{ or say } \underline{80 \text{ gallons.}}$$

Hydraulic Rams.—Where sufficient water is available for working hydraulic rams, they are very suitable for automatically raising water for supplying mansions, farms, hotels, hamlets, etc. These appliances may be divided into two classes, viz., those which raise a portion of the water which operates them, and those which utilise the energy from one source in order to raise water from a separate source. The latter are occasionally termed ram-pumps. Each class of ram varies widely in constructional details, but when well

constructed rams will work with a very small head of water. A head of 18 inches and a little less is sufficient to operate certain rams of the first class, provided they are properly fixed. For every foot of working head, water may be raised by a ram through a height of over 50 feet, but the efficiency of this appliance rapidly falls when only small heads are used to force water to high elevations.

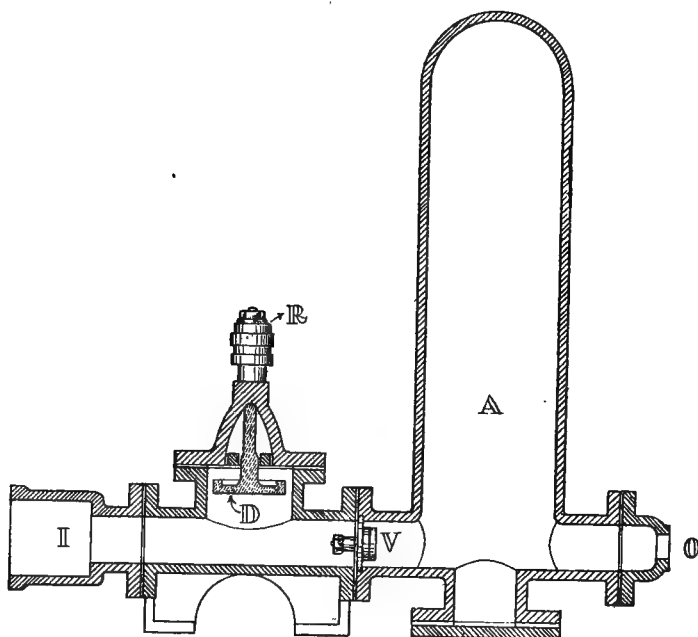


FIG. 216.—Walter Simpson's hydraulic ram.

A section of a ram by Walter Simpson, Aberdeen, is given in Fig. 216, the inlet being at I and the outlet at O. The ram contains two valves, the larger one D being known as the dash valve, and the smaller one V acts as a non-return valve. It will be observed that the dash valve is closed with an upward motion, whilst the non-return valve opens in the direction of the flow.

For its action, the ram depends upon the velocity of the inflowing water being suddenly arrested by the closing

of the dash valve D, when the pressure inside the ram is suddenly raised. At the period of maximum pressure a small volume of water is forced through the valve V into the air-vessel, from which it passes through the outlet O into the rising main. Although water escapes into the air-vessel, the resistance to its entrance is sufficient to cause the water in the supply pipe to recoil when the dash valve opens by its own weight. As soon as the energy which produces the recoil or backward motion has been expended, the water in the supply pipe again regains its forward flow, and after a brief interval, during which a certain volume escapes through the open dash valve, the latter is again suddenly closed and the operations repeated.

In Fig. 217 a ram is shown in position, together with the drive and delivery pipes. This illustration will also aid in making clear some of the points which require consideration in ram work. For the successful working of a ram, the drive pipe plays a very important part; if this pipe is too short, the dash valve beats too rapidly, and the ram will not do effective duty, owing to insufficient resistance being offered to the recoil of water when the dash valve is closed. To make the point clear we will assume that the length of drive pipe to a ram is, say, 15 feet; and that the working head is 10 feet, which is represented by H in Fig. 217; let the height through which water requires to be raised be, say, 100 feet. Under these conditions

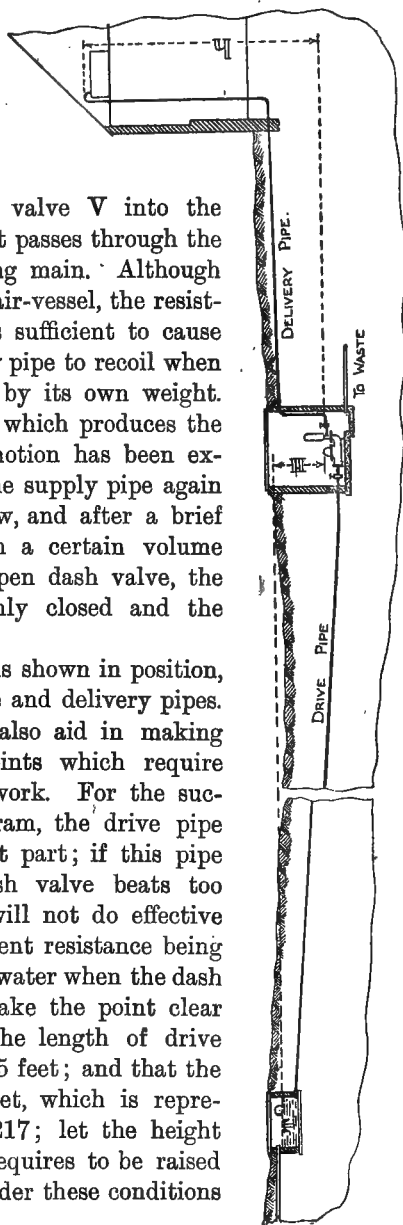


FIG. 217.—Hydraulic ram with drive and delivery pipes.

the working head is 10 feet and the resistance to be overcome is that due to a head of 100 feet. Now, in order for the ram to raise water, the pressure inside it when the dash valve is closed will require to exceed that due to the head on the delivery side. When a ram is working, two forces operate to relieve the increased pressure which is due to the sudden closing of the dash valve; one is the water which escapes through the retaining valve and into the air-vessel, and the other is the recoiling water in the drive pipe. If, now, the resistance offered to the recoil of water is less than that due to the opening of the retaining valve, the dash valve will beat, and the ram will appear to be working, when in reality no water is being raised. In the case under consideration, where the length of the drive pipe is only 15 feet, the resistance offered to the recoil would be insufficient, and in consequence the increased pressure would be principally relieved by the drive pipe, and the recoil would occur at a quicker rate.

For reasons stated it becomes obvious that a long drive pipe is essential, and as a general rule it should not be less in length than the height through which water requires to be raised. Long drive pipes require to be of adequate size, otherwise the dash valve will not close quickly enough. When the recoil in a drive pipe takes place, the water is affected through the whole of its length, so the longer the pipe the greater the internal resistances, and the longer the interval between the beats of the ram.

When laying a supply or drive pipe, it should have a gradual rise from the ram to the source of supply as in Fig. 217, and where bends are necessary they should be made as easy as practicable. A rose, or strainer, should be provided at the inlet end of the drive pipe, to prevent foreign matter passing into it and so interfering with the working of the ram.

Either iron or lead drive pipes may be used according to the size required, but when cast-iron spigot and socket pipes are adopted the joints should be made with rust cement. Lead is not a suitable jointing material in this case, as the joints require to be made with a material which imparts a greater degree of rigidity. Yielding joints on a drive pipe impair the efficiency of a ram.

When rams have a high working head they are subjected to considerable strain, and as a rule it should not exceed 30 feet.

Where possible the supply of water to a ram should be sufficient to maintain a constant head upon it, or, in other words, the supply tank T, Fig. 217, should be always full. When, however, a ram is supplied by a spring or stream which has a varying yield, a much larger supply tank will be necessary than where a large and fairly constant volume of water is available. Should a supply tank become emptied by the outflow exceeding the rate of inflow, the ram will cease to work, and the water available will flow through the open dash valve and thence to waste. To obviate this waste of water a float valve may be attached to the end of the drive pipe in the supply tank, in order to automatically shut off the supply to the ram when the water level has been lowered to a certain point. During the refilling of the tank the float valve opens, and the ram can then be restarted by holding down the dash valve for a few seconds, or by means of a pumping valve at the supply tank. The reason why the ram does not restart itself is due to the gradual closing of the dash valve when the supply is being cut off.

Air-vessels for rams should be of a large size, in order that water at each beat may be first directly discharged into them, without much compression of the contained air. Rams occasionally fail to raise water owing to their air-vessels getting water-logged; the beating of the dash valves may continue, but the resistance on the delivery side is too great when it is necessary to first put the water in the rising main in motion. When a ram is in constant use the air-vessel should be recharged with air at regular intervals of, say, once a week. In a ram the water is under more or less considerable pressure when it enters the air-vessel, and therefore the capacity of water for the absorption of air is increased, and, owing to the water in the air-vessel being continually changed, the latter, in consequence, is gradually deprived of its contained air.

To renew the air, one or two cocks are provided at the base of an air-vessel, and when these are opened and the

valves on the drive and delivery pipes are closed, the vessel is readily charged with air. In many rams a small air or snuffle valve is provided for making good a portion of the air, but it cannot be entirely relied upon for automatically supplying the requisite volume, although it will lengthen the interval between the periods of recharging as above described. An air or snuffle valve opens and admits air during the recoil of the drive water, and it is forced along with water into the air-vessel at each beat of the ram.

The principal causes for rams getting out of order are due to faulty dash or retaining valves, to air-vessels getting water-logged, to defects in the pipes, to air in the drive pipe, and to an insufficient supply of water.

Within certain limits a ram can be made to use less water by shortening the stroke of the dash valve by adding one or more washers as at R, Fig. 216, but the volume of water raised is also diminished, and the pulsations of the ram are made at a quicker rate. If a ram has never given satisfaction, this may be due to structural defects, or to the drive pipe being irregularly laid so as to permit of the lodgment of air, or to the drive pipe being too small, or of sufficient length. The leakage of a non-return valve, or the lodgment of air in a drive pipe, causes the dash valve to remain closed. A defect in the lower part of a delivery pipe would also have a similar effect. Water-logged air-vessels, and drive pipes which are too short, allow pulsations to continue without raising water.

When a ram is newly started, the water will, of course, rise in the delivery pipe to the same level as that in the supply tank. At this period, provided there is an ample supply of water, the dash valve will be closed, and in order to start the ram it will be necessary to open the dash valve several times, by hand, until water is forced through the delivery pipe to a height which offers sufficient resistance, to bring about the recoil of the water in the drive pipe.

With regard to the volume of water a ram will raise, this can be calculated when its efficiency for the given conditions is known. When a certain volume of water flows through a

drive pipe, its energy is usually calculated in foot-pounds. This is obtained by multiplying the weight of water by the height through which it falls. For example, if the working head on a ram is 10 feet, and 100 lb. of water are delivered to it per minute, the energy in the drive water for the time given is equal to $100 \times 10 = 1000$ ft.-lb. Assuming that 10 lb. of water are raised in the same interval of time through a height of 90 feet, then the energy to raise this volume through the height given, when frictional resistances are neglected, is equal to $10 \times 90 = 900$ ft.-lb. But as the drive water contains 1000 ft.-lb. of energy, then $(1000 - 900) = 100$ ft.-lb. which are absorbed by friction and by leakage, etc. Under these circumstances the efficiency of the ram would be $\frac{900 \times 100}{1000} = 90$ per cent.

Of the 100 lb. of water which are delivered to the ram only 10 lb. are raised, the remaining 90 lb. escape through the dash valve and flow away to waste.

For making calculations in connection with rams the following formulæ may be used:—

[illegible]

$$G = \frac{h \times q}{H \times e} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (45)$$

$$e = \frac{h \times q}{G \times H} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (46)$$

Where G = gallons supplied to ram in any given time.

„ q = gallons raised during the same interval of time.

„ H = head of water upon ram.

„ h = height through which water is raised.

„ e = efficiency of ram.

In Fig. 217 H and h are indicated. Only approximate values of e can be given, as these vary with different ratios of H and h , and with different makes of rams. The efficiency of a ram is also influenced by the manner in which it is fixed.

TABLE VI
VALUES OF e

Where $\frac{h}{H} =$	2	3	4	5	6	9	12	15	20
$e =$	.88	.85	.81	.75	.72	.63	.5	.4	.3

Example 21.—A ram when working with a full beat requires a supply of 12 gallons per minute. Assuming that the ram has an efficiency of 85 per cent. when raising water through a height of 120 feet, and when the working head is 19 feet, how many gallons should it raise per hour?

Supply per hour = $12 \times 60 = 720$ gallons.

By Formula 44, $q = \frac{G \times H \times e}{h}$.

Substituting values, $q = \frac{720 \times 19 \times .85}{120}$;

$\therefore q = 96.9$, or say 97 gallons per hour.

Example 22.—In 24 hours a ram delivers 140 gallons through a height of 160 feet. If the working head is 15 feet, efficiency of ram 64 per cent., determine the rate of supply per minute the ram will require.

The volume of water raised per minute

$$= \frac{140}{60 \times 24} = .097 \text{ gallon.}$$

Using Formula 45, $G = \frac{h \times q}{H \times e}$.

Substituting values given, $G = \frac{160 \times .097}{15 \times .64}$;

$\therefore G = 1.6$ gallons per minute as the volume required.

Example 23.—Find the efficiency of a ram which raises 950 gallons per day through a height of 75 feet, when the rate of supply is 18,000 gallons per day and when the working head is 7 feet.

By Formula 46, $e = \frac{h \times q}{G \times H}$.

Substituting values given, $e = \frac{75 \times 950}{18000 \times 7}$;

$\therefore e = .565$, or $56\frac{1}{2}$ per cent.

The following table gives approximate sizes of drive and delivery pipes for rams :—

TABLE VII

Water delivered to ram per minute.	Diameter of drive pipe.	Diameter of delivery pipe.
1 to 3 gallons.	1 inch.	$\frac{1}{2}$ inch.
3 „ 8 „	$1\frac{1}{2}$ „	$\frac{3}{4}$ „
8 „ 16 „	2 „	1 „
16 „ 24 „	$2\frac{1}{2}$ „	$1\frac{1}{4}$ „
24 „ 32 „	3 „	$1\frac{1}{2}$ „
32 „ 50 „	$3\frac{1}{2}$ „	$1\frac{3}{4}$ „
50 „ 60 „	4 „	2 „

A hydraulic ram of the second type, by Keiths, Blackman & Co. Ltd., is shown in Fig. 218. With this appliance, a pure and limited supply of water can be raised by means of impure water, when the latter is obtainable in sufficient volume. The two waters are not able to mix, as each is supplied to separate parts of the appliance, and any leakage at the pistons is free to escape to the exterior of the ram. From the figure it will be observed that the lower part resembles an ordinary ram, whilst the upper part resembles a single action pump.

Where practicable, the pure water should flow by gravity to the appliance, but if this is not possible, then it may be raised a few feet through a suction pipe. The action of the ram pump shown is as follows, where the pure water will flow by gravitation to the ram. When the piston R is in the position shown, water flows through the non-return valve V_1 , and fills the cylinder C. The impure water which supplies the motive power enters at A, and when the dash valve D is rapidly closed, the energy due to concussion is exerted on the piston P_1 , which is directly joined by means of rod R to the upper piston P_2 . With each beat of the dash valve, the pistons are caused to rise, and to displace the pure water from cylinder C, through the retaining valve V_2 and into the air-vessel; from the latter, the water flows through the delivery pipe to the point desired. During the recoil of the water in

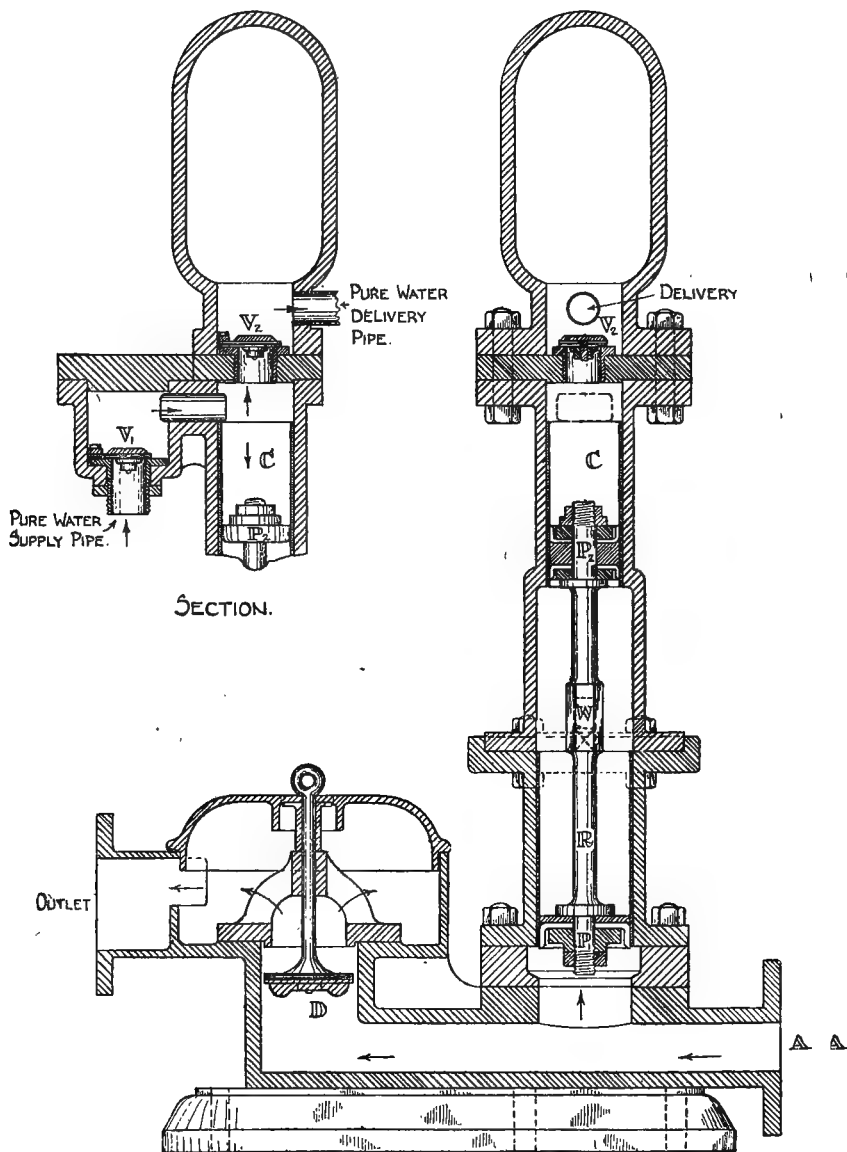


FIG. 218.—Keith and Blackman's hydraulic ram pump.
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the drive pipe the dash valve opens, the pistons descend, and the cylinder C receives a fresh charge of pure water. These operations are repeated so long as the ram continues to work satisfactorily. To aid the downward motion of the pistons, a weighted lever operates on the rod at W. It is now clear why pure water should flow by gravity to the ram, for as it requires to be raised by the downward motion of the pistons, the power available is only that obtained by means of the weighted lever.

CHAPTER XII

HYDROSTATICS AND HYDRAULICS

Hydrostatics is that branch of science which treats upon the equilibrium of fluids. In this case it is confined to the pressure of fresh water when the latter is at rest.

If a cistern forms a cube, and each side is 1 foot long, the weight of water the cistern will hold when full is 62·4 lb. This value also represents the pressure which would be exerted on the bottom of the cistern, but as its sides are acted upon as well, the total pressure exerted by the water is not synonymous with its weight.

Under the force of gravity, pressure is due to head of water, and upon any unit area in a horizontal plane the pressure is the same. For example, if a cistern is 4 feet deep, and is filled with water, the internal pressure on the bottom per square foot of surface equals $62\cdot4 \times 4 = 249\cdot6$ lb. On a vertical surface the pressure varies with the depth of water, being zero at the water level, and a maximum along the bottom edge.

In Fig. 219, the lengths of the horizontal broken lines which are enclosed by the triangle ABC represent pressures at different depths, BC being equal to AB, or to the depth of water in the tank. To calculate the pressure on a vertical surface, it is necessary to know the average head of water which acts upon that surface. For example, the average head on the side AB, Fig. 219, is $\frac{AB}{2}$, or half the depth of the water. Should the average head be required for a portion of a vertical surface such as *ef*, Fig. 219, then this would be $\frac{h_1 + h_2}{2}$ where h_1 and h_2 represent the heads upon *e* and *f* respectively. If $h_1 = 2$ feet

and $h_2=3$ feet, the pressure acting upon each square foot of surface between the points given equals $\frac{2+3}{2} \times 62.4 = 156$ lb.

As the pressure per sq. foot per foot of head is equal to 62.4 lb., the pressure per sq. inch for each foot of head equals $\frac{62.4}{144} = .433$ lb.

If a closed receptacle, such as a cylindrical tank or boiler, be supplied with water from an overhead cistern, the pressure of the water is transmitted over the whole internal surfaces of the vessel, and the intensity of the pressure at any point is

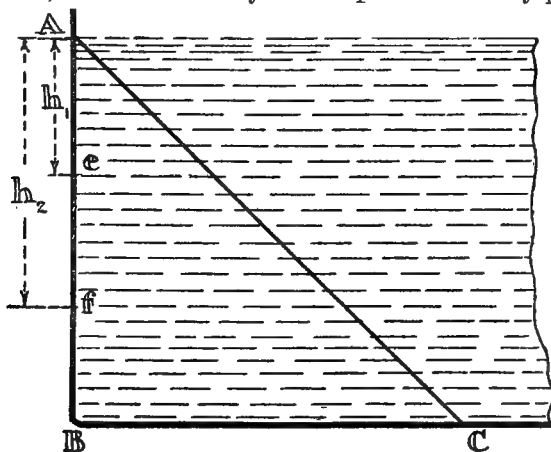


FIG. 219.—Diagram illustrating water pressure.

proportional to the head of water above that point. On any given horizontal surface, pressure is transmitted over the whole area with undiminished force, and it acts at right angles to the surfaces. The length and diameter of a supply pipe in no way affects the pressure transmitted upon a surface, when water is at rest, although both size and length materially affects the discharging capacity of a pipe. From this, it becomes clear that, if pressure is transmitted upon a horizontal surface by means of a supply pipe, the total pressure on that surface is equal to the weight of water contained in a cistern whose plan is the same as that of the surface, and whose depth is equal to the head of water under consideration.

For determining pressures the following formulæ may be used:—

$$P = A \times 62.4 \times h \quad . \quad . \quad . \quad . \quad . \quad . \quad (47)$$

$$P = a \times .433 \times h. \quad . \quad . \quad . \quad . \quad . \quad . \quad (48)$$

$$p = h \times .433 \quad . \quad . \quad . \quad . \quad . \quad . \quad (49)$$

Where P = total pressure in lbs.

„ p = pressure in lbs. per sq. inch.

„ A = sectional area of surface in sq. feet.

„ a = sectional area of surface in sq. inches.

„ h = head of water in feet.

With the formulæ 47 and 48 it is necessary to either find the area of a surface or to substitute values which produce it, but modified formulæ may be used for special cases. Thus, to determine the pressure on the inner surfaces of cylindrical vessels, the formulæ may take the form given below.

Formulæ for determining the total pressure on the Sides of Cylindrical Vessels—

$$P = D \times 196 \times h \times L \quad . \quad . \quad . \quad . \quad . \quad . \quad (50)$$

$$P = d \times 1.36 \times h \times l \quad . \quad . \quad . \quad . \quad . \quad . \quad (51)$$

Formulæ for obtaining total pressures on the ends of Cylindrical Vessels and on Pistons, etc.—

$$P = D^2 \times 49 \times h \quad . \quad . \quad . \quad . \quad . \quad . \quad (52)$$

$$P = d^2 \times .34 \times h \quad . \quad . \quad . \quad . \quad . \quad . \quad (53)$$

$$\text{from which, } h = \frac{P}{d^2 \times .34} \quad . \quad . \quad . \quad . \quad . \quad . \quad (54)$$

Where P = total pressure in lbs.

„ D = diameter in feet.

„ d = diameter in inches.

„ h = head of water in feet.

„ L = length of pipes or cylinder in feet.

„ l = length of pipes or cylinder in inches.

A few worked examples will aid to show the range of problems to which the above rules may be applied.

Example 24.—Find the total distributed pressure, and the average pressure per square inch, on the vertical surface of a copper hot-water tank which is 1 ft. 9 in. diameter and

3 ft. 6 in. high, when the head of water above the centre of the cylinder is 36 feet.

Using Rule 50, $P = D \times 196 \times h \times L$.

Substituting values given, $P = 1\frac{3}{4} \times 196 \times 36 \times 3\frac{1}{2}$;

$\therefore P = 43,218$ lb. total distributed pressure on vertical surface.

For the second part of the problem use Formula 49.

Where $p = h \times .433$,

$p = 36 \times .433$;

$\therefore p = 15.58$, or about 16 lb. per sq. inch.

Example 25.—If a 6-inch diameter drain is tested for soundness by the hydraulic test, determine the total force which tends to displace the stopper, if the latter is subjected to a mean head of 12 feet of water.

By Formula 53, $P = d^2 \times .34 \times h$.

Substituting values given, $P = 6^2 \times .34 \times 12$;

$\therefore P = 146.88$, or nearly 147 lb.

Example 26.—What is the total distributed pressure which acts upon one side of a cistern which is 6 ft. 6 in. long, 4 ft. 6 in. wide, and 3 ft. 9 in. deep? The highest water level is 3 inches below the top of cistern.

Average head on side $= \frac{3' 9'' - 3''}{2} = 1\frac{3}{4}$ feet, and area of surface pressed upon $= 6\frac{1}{2} \times 3\frac{1}{2}$.

Using Formula 47, $P = A \times 62.4 \times h$.

Substituting values given, $P = 6\frac{1}{2} \times 3\frac{1}{2} \times 62.4 \times 1\frac{3}{4}$;

$\therefore P = 2484.3$ lb.

Example 27.—A dead-weight safety valve is loaded to the extent of 6 lbs. Assuming the valve orifice is $\frac{5}{8}$ inch diameter, find the head of water which will exert pressure equal to the load given.

Formula 54 gives $h = \frac{P}{d^2 \times .34}$.

Substituting values given, $h = \frac{6}{(\frac{5}{8})^2 \times .34}$;

$\therefore h = 45.17$, or say 45 feet.

In the last problem the load on the valve represents the total pressure which tends to close it, and therefore takes the value of P as shown.

Hydraulics is that branch of science which treats on liquid when in motion. To put water into motion, a certain amount of pressure is required, which depends upon the nature and magnitude of the resistances to be overcome.

If a house is supplied by water from a tank in an elevated situation, the pressure of the water at any point in the supply pipe, provided the water is at rest, is equal to the vertical distance between that point and the surface of the water in the supply tank. Should a draw-off tap, however, be partly opened, the water in the pipe is put into motion, and the pressure is reduced. If the tap is opened wide, the pressure in the pipe is still further reduced.

The principal factors which require taking into account when ascertaining the flow of water through pipes and orifices are as follows:—

- (a) Pressure absorbed in overcoming the inertia of the water to put it into motion.
- (b) The form the outlet orifice takes.
- (c) Pressure absorbed by pipe friction.
- (d) Pressure absorbed by sudden contractions in pipes, and by abrupt changes of direction.

When pipes are of considerable length, the pressure absorbed by (a) and (b) is a negligible quantity, as it is so small when compared with that absorbed by pipe friction. On the other hand, the pressure absorbed by (a) and (b) when pipes are short is of more importance, as it may represent a large percentage of the total pressure.

The form of an orifice affects the rate of discharge, because the stream lines converge to a more or less extent to form a contracted neck—*vena contracta*—just beyond the opening through which the stream lines issue, and instead of the sectional area of flow being equal to that of the orifice, it is only equal to the area of the contracted part. It is not, of course, possible to measure the point of greatest contraction for different forms of orifices under ordinary conditions, but, as there is a definite relationship between the area of contraction

and that of an orifice, the latter area is expressed as a ratio of the former, and termed a coefficient. Thus, for a short tube of 1 inch diameter, the stream at the point of greatest contraction measures $\cdot 9$ or $\frac{9}{10}$ inch diameter, and the ratio of the area of the tube to that of the contracted neck is $\frac{\cdot 9^2}{1^2} = \cdot 81$.

Suppose now we require to find the discharge through a short tube, when the water at the point of greatest contraction has a velocity of v feet per second, and where A equals the area of the tube in feet. The volume of water discharged by the tube would equal $\cdot 81 \times v \times A =$ cubic feet per second.

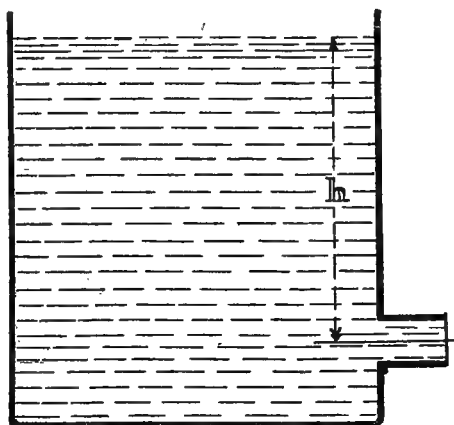


FIG. 220.—Illustrating head of water above orifice.

Multiplying by $\cdot 81$ makes the necessary correction for the *vena contracta* in this case.

Coefficient for orifice in thin plate . . .	= $\cdot 62$
„ „ good shaped nozzle . . .	= $\cdot 94$
„ „ short tube where length equals 2 to 3 diameters = $\cdot 81$	
„ „ short tube where length equals 4 to 12 diameters = $\cdot 77$	
„ „ short tube where length equals 13 to 24 diameters = $\cdot 73$	

Flow of Water through Orifices and Short Tubes.—The maximum velocity with which water issues through an orifice

or short tube in the side of a cistern, Fig. 220, is nearly the same as that acquired by a body which has fallen from rest through a height h , which is measured from the centre of the orifice to the water surface.

The velocity of a falling body is found by the general formula—

[illegible]

Where v = velocity in feet per second.

„ $g = \text{force of gravity} = 32.2.$

„ h = height fallen through in feet.

For finding the discharge in gallons, the velocity formula may be modified to take the form beneath.

$$G = d^2 \times 16.3 \times c \times \sqrt{h} \quad . \quad . \quad . \quad . \quad . \quad (56)$$

Where G = gallons discharged per minute.

„ d = diameter of orifice in inches.

" c = coefficient which varies with the form of orifice. (See page 345.)

„ h = head of water above centre of outlet.

Further simplification is possible for formulæ in connection with any special form of aperture ; thus, for a short tube, where $c = 81$ the two constants may be multiplied together, when we have $16.3 \times 81 = 13.2$. In practice the decimal fraction may be omitted and the value taken as 13.

Formula for Short Tube.—

$$G = d^2 \times 13 \times \sqrt{\hbar} \quad . \quad . \quad . \quad . \quad (57)$$

$$\text{By transposition } d = \sqrt{\frac{G}{13 \times \sqrt{h}}} \quad . \quad . \quad . \quad . \quad (58)$$

$$\text{and } h = \left(\frac{G}{d^2 \times 13} \right)^2 \quad . \quad . \quad . \quad . \quad (59)$$

Example 28.—If a short tube of $1\frac{1}{4}$ inch diameter is under a constant head of 2 ft. 6 in., find its rate of discharge. (See Fig. 220.)

By Formula 57, $G = d^2 \times 13 \times \sqrt{h}$.

Substituting values given, $G = (1\frac{1}{4})^2 \times 13 \times \sqrt{2.5}$.

$$G = \frac{5}{4} \times \frac{5}{4} \times \frac{13}{1} \times \frac{1.58}{1};$$

$\therefore G = 32.09$, or say 32 gallons per minute.

Example 29.—What head of water would be necessary to discharge 15 gallons per minute through a short tube of 1 inch diameter?

$$\text{By Formula 59, } h = \left(\frac{G}{d^2 \times 13} \right).$$

$$\text{Substituting values given, } h = \left(\frac{15}{1^2 \times 13} \right)^2 = \frac{225}{169};$$

$$\therefore h = \underline{1.33 \text{ feet, or say 1 ft. 4 in.}}$$

Flow of Water through Long Pipes.—When water is flowing through pipes of more or less considerable length, the chief resistance is that offered by the surfaces of the pipes. The velocity of a particle of water varies according to its distance from the surface of a pipe, this being greatest at the centre, and the least against the surfaces of the pipe. Because the velocity throughout the cross sectional area is not uniform, the size and condition of a pipe have a marked effect upon its average, or mean velocity of flow.

Speaking generally, when water is flowing through a pipe its mean velocity is proportional to the square root of its hydraulic mean depth, to the square root of the pressure head, and inversely proportional to the square root of its length.

By the aid of the following formulæ many problems in connection with long pipes may be solved. These make allowance for bends in pipes, when the latter are laid or fixed in the usual manner.

Formulæ for Long Pipes.—

$$G = \sqrt{\frac{d^5 \times f \times h}{l}} \quad . \quad . \quad . \quad . \quad . \quad . \quad (60)$$

$$h = \frac{G^2 \times l}{d^5 \times f} \quad . \quad . \quad . \quad . \quad . \quad . \quad (61)$$

$$d = \sqrt[5]{\frac{G^2 \times l}{f \times h}} \quad . \quad . \quad . \quad . \quad . \quad . \quad (62)$$

$$d^5 = \frac{G^2 \times l}{f \times h} \quad . \quad . \quad . \quad . \quad . \quad . \quad (63)$$

Where G = gallons discharged per minute.

„ d = diameter of pipe in inches.

„ h = head of water in feet.

„ l = length of pipe in feet.

„ f = a coefficient which varies with the size of pipes and is given in the following table:—

TABLE VIII

VALUES OF f

Lead pipes from $\frac{1}{2}$ inch to 1 inch diameter	.	.	$f=210$
„ „ „ $1\frac{1}{4}$ „ „ „	.	.	$f=260$
Iron „ „ „ $1\frac{1}{4}$ „ „ „	.	.	$f=210$
„ „ „ 2 „ 3 „ „	.	.	$f=330$
„ „ „ $3\frac{1}{2}$ „ 5 „ „	.	.	$f=460$
„ „ „ $5\frac{1}{2}$ „ 7 „ „	.	.	$f=570$

To use Formulæ 60 to 62 easily, a knowledge of logarithms is necessary, but for those who are not familiar with this branch of mathematics, problems may be solved by the aid of the table below.

TABLE IX

Diameter pipe.	5th power diameter.	Diameter pipe.	5th power diameter.
$\frac{1}{2}$ inch.	03125	$3\frac{1}{2}$ inch.	525.218
$\frac{3}{4}$ „	2373	4 „	1,024.000
1 „	1.0000	$4\frac{1}{2}$ „	1,845.281
$1\frac{1}{4}$ „	3.0517	5 „	3,125.000
$1\frac{1}{2}$ „	7.594	$5\frac{1}{2}$ „	5,032.843
2 „	32.000	6 „	7,776.000
$2\frac{1}{2}$ „	97.656	$6\frac{1}{2}$ „	11,602.906
3 „	243.000	7 „	16,807.000

When a pipe is used for conveying water from a storage tank T to a point P, Fig. 221, and when discharging full bore, the head absorbed by friction at different points of the pipe is represented by the vertical distances between the hydraulic grade line No. 1, and the horizontal line L; the latter repre-

sents the level of the water in the supply tank. The vertical distances between No. 1 hydraulic grade line and the water pipe indicate the static pressure at any point when the pipe is discharging full bore. The hydraulic grade line simply indicates the level to which water would fall in vertical tubes, were it practicable to obtain them sufficiently long and to join them with the pipe in question.

In Fig. 221 the pipe is supposed to be of uniform bore from end to end, and the hydraulic grade line is shown to form a straight line from T to P. A true hydraulic grade line, however, like the one shown, can only be obtained when the whole of the pipe line is below it.

Example 30.—Find the gallons discharged per minute by a 3-inch cast-iron pipe at the point P, Fig. 221, when the head of water and length of pipe are as shown.

Total head of water available above P = $360 - 100 = 260$ feet.

Length of pipe given is 6500 feet.

By Formula 60,

$$G = \sqrt{\frac{d^5 \times f \times h}{l}}$$

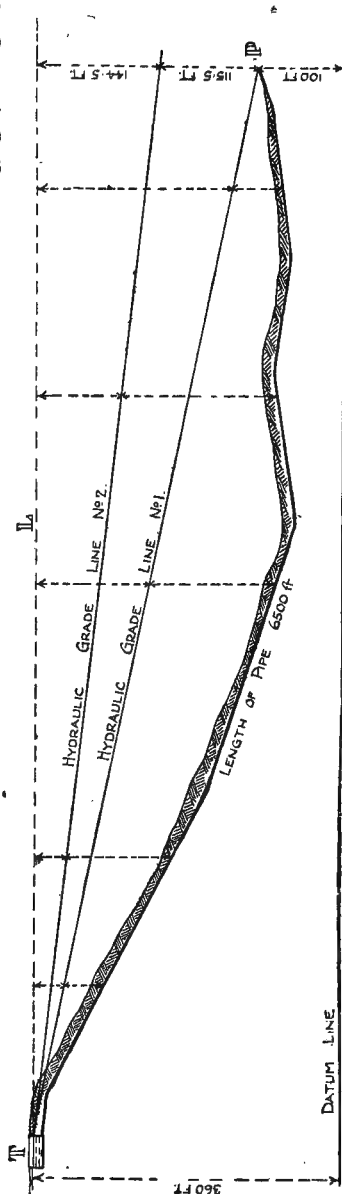


FIG. 221.—Diagram illustrating hydraulic gradient.

In Table VIII. it will be found that the value of f for a 3-inch pipe is 330, and in Table IX. the 5th power of a 3-inch pipe = 243.

$$\text{Substituting values, } G = \sqrt{\frac{243 \times 330 \times 260}{6500}},$$

$$G = \sqrt{3207.6};$$

$$\therefore G = \underline{56.6}, \text{ or say } \underline{57 \text{ gallons per minute.}}$$

In this calculation the whole of the head has been utilised in discharging 57 gallons per minute at point P. Suppose, however, a discharge under a given higher pressure is required at P; under the latter conditions the whole of the 260 feet of head would not be available for forcing the water through the pipe, and the hydraulic grade line would require to be raised.

Example 31.—What diameter of pipe would be required to discharge 100 gallons per minute under a pressure of 50 lb. per sq. inch, at P, Fig. 221, when the length of pipe and head are as shown?

The equivalent of 50 lb. per sq. inch is $50 \times 2.31 = 115.5$ feet head. The value 2.31 represents the head in feet which exerts a pressure of 1 lb. per sq. inch.

For delivering the volume required, the head available will be $360 - (100 + 115.5) = 144.5$ feet.

$$\text{Now by Formula 62, } d = \sqrt[5]{\frac{G^2 \times l}{f \times h}}$$

The value of f , however, is a variable quantity, and we do not know the precise value to assign to it when beginning the problem. It is therefore necessary to select a trial value of f , and if it does not agree with the diameter obtained, as shown in Table VIII., the problem must be reworked with either a lower or a higher value, as may be found necessary. We will assume the diameter required is somewhere between $3\frac{1}{2}$ and 5 inches, and for this range the value of f in Table VIII. is given as 460.

$$\text{Substituting values, } d = \sqrt[5]{\frac{100^2 \times 6500}{460 \times 144.5}}$$

Working by logarithms—

$$\text{Log. } 100^2 = 4 \qquad \text{Log. } 460 = 2.6628$$

$$\text{Log. } 6500 = 3.8129 \qquad \text{Log. } 144.5 = 2.1599$$

$$\underline{7.8129} \qquad \underline{4.8227}$$

$$4.8227$$

$$5\text{th root } 5)2.9902$$

$$\underline{.5980}$$

$$\text{Anti log. } .598 = 3.963;$$

$$\therefore d = 3.963, \text{ or say } \underline{4 \text{ inches diameter.}}$$

This problem may be worked by ordinary arithmetic with the aid of Formula 63 and Table IX.

$$\text{By Formula 63, } d^5 = \frac{G^2 \times l}{f \times h}.$$

$$\text{Substituting values as before, } d^5 = \frac{100^2 \times 6500}{460 \times 144.5};$$

$$\therefore d^5 = 977.8.$$

Upon reference to Table IX. it will be found that the 5th power of $3\frac{1}{2} = 525$; this value, however, is too low, and the diameter which agrees with the next higher value is the size required.

As before, the pipe required is of 4 inches diameter.

When water is discharged at the point of escape under a pressure of 50 lb. per sq. inch for the conditions shown in Fig. 221, the hydraulic grade line is raised to the position occupied by the straight line No. 2.

If a pipe line follows the general configuration of the earth's surface, as in Fig. 222, it should form two sections of different diameters. The first section would be from A to B, and the other from B to C, each having its own hydraulic grade line as shown. If a certain volume is required per minute at C, it is obvious that a similar volume must first be delivered in the same time at B. When comparing the two sections, that from A to B is 8200 feet long, and the maximum head above the latter point is 35 feet; for the section BC the total length is 650 feet, and the vertical distance between B and C is 185 feet. Thus the head for the shorter section is more than 5 times that for the longer section, and it becomes obvious

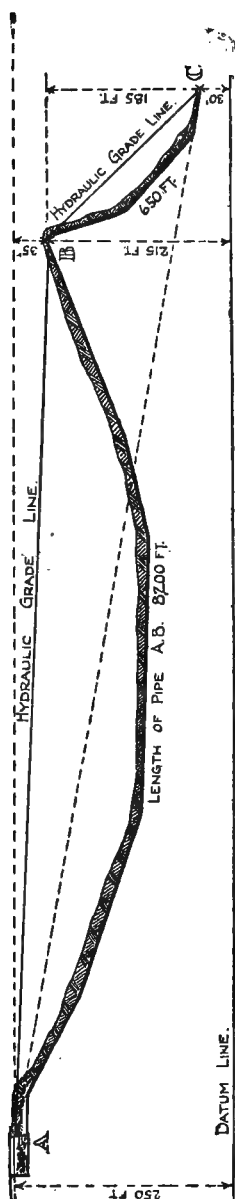


FIG. 222.—Diagram illustrating hydraulic gradient.

that, in order for the longer section to deliver a volume equal to the discharging capacity of the shorter section, the former must be of a larger size.

Should a pipe from A to C, Fig. 222, be of uniform bore, the length BC would be never fully gorged. A straight line from A to C, as shown by the dotted line, would not be a true hydraulic grade line, because it falls below the pipe which rises to B, and under such circumstances would have a negative value.

Assuming that a pipe of uniform bore were used for the conditions given in Fig. 222, the maximum head available for forcing water through the pipe would be 35 feet, which is the vertical distance between point B and the level of the water in the tank.

Example 32.—Assuming a line of pipes follows the general contour of the ground surface as in Fig. 222, determine the sizes of the pipes to deliver 120 gallons of water at C, when the head and lengths of pipes are as shown.

Total head for section AB = 250
 — 215 = 35 feet.

Length of pipe given = 8200 feet.

Pipe for Section AB.—

$$\text{By Formula 63, } d^5 = \frac{G^2 \times l}{f \times h}.$$

It will be necessary to use a trial value for f , and if we assume the pipe required will be between 5 and 7 inches diameter, the value of f from Table VIII. is 570.

Substituting values given, $d^5 = \frac{120^2 \times 8200}{570 \times 35}$;
 $\therefore d^5 = 5919$.

From Table IX. we find that a $5\frac{1}{2}$ -inch diameter pipe when raised to the 5th power = 5032.8, but, as this value is not large enough, the diameter which agrees with the next high value is the one required;

\therefore Pipe for section AB will be 6 inches diameter.

Pipe for Section BC.—

Head upon C from point B = $215 - 30 = 185$ feet.

Length of Section BC = 650 feet.

By Formula 63, $d^5 = \frac{G^2 \times l}{f \times h}$.

As this pipe will be smaller than the one for section AB, we will assume that its diameter will lie somewhere between 2 and $3\frac{1}{2}$ inches. For this range of sizes the value of f , Table VIII., is 330.

Substituting values given, $d^5 = \frac{120^2 \times 650}{330 \times 185}$;
 $\therefore d^5 = 153$.

In Table IX. we find that the nearest diameter when raised to the 5th power to agree with the above value is 3 inches;

\therefore Pipe for section BC will be 3 inches diameter.

Short Pipes.—When pipes are short, the head to generate velocity at entry requires to be taken into account, and also that absorbed by branches and special fittings. For these conditions the head absorbed by friction may be obtained by the following formula:—

$$h = \frac{G^2 \times e}{d^4 \times 267} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (64)$$

Where h = loss of head in feet.

„ d = diameter of pipe in inches.

„ G = gallons discharged per minute.

„ e = a coefficient from Table X,

TABLE X.

For a plain pipe end in a tank	$e=1.58$
„ trumpet-shaped end of pipe in tank	$e=1.18$
„ right-angled branch in pipe	$e=1.25$
„ plug tap when branched into pipe	$e=1.4$
„ screw down tap when branched into pipe	$e=1.8$

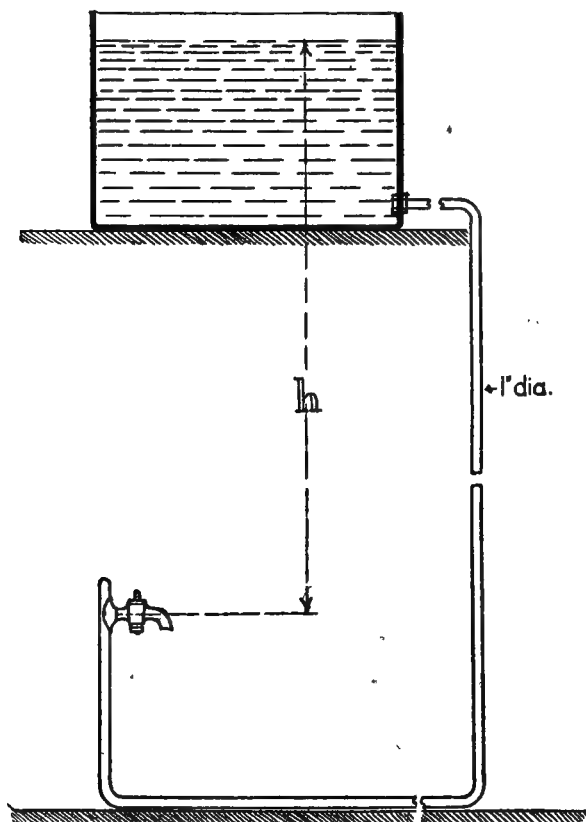


FIG. 223.—Flow of water through pipes.

If we assume that water is withdrawn from an overhead cistern, as in Fig. 223, where the draw-off pipe is comparatively short, the resistances offered by the tap and by the pipe end in the cistern may influence the discharge to a considerable extent.

It is not possible to directly calculate the discharge by a short pipe, as the different resistances are not known at the outset. An indirect method is therefore adopted for calculating the discharging capacity of short pipes, which consists of first ascertaining the total head to yield an assumed discharge. When this head is known for the assumed discharge, the discharge for any other head can be obtained by proportion, so long as the conditions with regard to size and length of pipes remain unaltered.

The discharging capacity of pipes and fittings varies directly as the square root of the pressure head. If, therefore, it is found that a water pipe gives a discharge of 6 gallons per minute when under a head of 9 feet, the same pipe would discharge under a head of 1 foot $\frac{6 \times \sqrt{1}}{\sqrt{9}} = 2$ gallons per minute, and for a head of 16 feet $\frac{6 \times \sqrt{16}}{\sqrt{9}} = 8$ gallons per minute.

*Example 33.*¹—Determine the volume of water that would be discharged in 10 minutes by a plug tap, as in Fig. 223, when the tap is subjected to a constant head of 12 feet. The diameter of the pipe is 1 inch, and its length will be assumed to be 28 feet.

The principal resistances to be considered are those due to—

- (a) Water entering the pipe.
- (b) Length of pipe.
- (c) Plug tap.

As it is necessary to ascertain the head absorbed for an assumed discharge before the actual discharge can be calculated, we will take the assumed discharge as 10 gallons per minute.

Head absorbed by friction.

- (a) Head absorbed by water when entering pipe.

$$\text{By Formula 64, } h = \frac{G^2 \times e}{d^4 \times 267}.$$

Value of e from Table X. = 1.58.

¹ The horizontal portion of the pipe leaving the tank would require to be very short in this case, otherwise the head h (see Fig. 223) could not be fully absorbed for reasons explained on page 352.

Substituting values given, $h = \frac{10^2 \times 1.58}{1^4 \times 267}$;

$\therefore h = \underline{.59 \text{ feet.}}$

(b) Head absorbed by length of pipe.

By Formula 61, $h = \frac{G^2 \times l}{f \times d^5}$.

Value of f for a 1-inch pipe in Table VIII. = 210.

Substituting values, $h = \frac{10^2 \times 28}{210 \times 1^5}$;

$\therefore h = \underline{13.33 \text{ feet.}}$

(c) Head absorbed by plug tap.

Formula 64 gives $h = \frac{G^2 \times e}{d^4 \times 267}$.

Value of e from Table X. = 1.4.

Substituting values given, $h = \frac{10^2 \times 1.4}{1^4 \times 267}$;

$\therefore h = \underline{.52 \text{ feet.}}$

Total head to discharge 10 gallons per minute = .59 + 13.33 + .52 = 14.44 feet.

In the example only 12 feet are available as the pressure head, so the discharge for this will be:—

$$G = \frac{10 \times \sqrt{12}}{\sqrt{14.44}} = 9.1 \text{ gallons per minute};$$

$$\therefore \text{the volume discharged in 10 minutes} \\ = 9.1 \times 10 = \underline{91 \text{ gallons.}}$$

Suppose, now, we work Example 33, by omitting the resistance due to the water entering the pipe, and also that offered by the plug-cock.

By Formula 60, $G = \sqrt{\frac{d^5 \times f \times h}{l}}$.

Substituting values, $G = \sqrt{\frac{1^5 \times 210 \times 12}{28}}$;

$\therefore G = 9.48 \text{ gallons per minute.}$

In ten minutes the discharge = $9.48 \times 10 = 94.8 \text{ gallons.}$

The simple and the more abstruse methods of solving Example 33 only give a difference of $94.8 - 91 = 3.8$ gallons, which is not very much. The difference, however, is more marked when the ratio of the diameter to the length of the pipe has a smaller value, as the following example will show:—

Example 34.—Find the discharge per hour by a $1\frac{1}{2}$ -inch lead pipe when arranged in a similar manner to that given in Fig. 223, when the head of water upon the plug cock is 7 feet, and when the length of the pipe is 10 feet.

Assume a discharge of 20 gallons per minute.

(a) Head absorbed when entering pipe.

$$\text{By Formula 64, } h = \frac{G^2 \times e}{d^4 \times 267}.$$

$$\text{Substituting values, } h = \frac{20^2 \times 1.58}{(1\frac{1}{2})^4 \times 267};$$

$$\therefore h = \underline{.467 \text{ feet.}}$$

(b) Head absorbed by length of pipe.

$$\text{Formula 61 gives } h = \frac{G^2 \times l}{f \times d^5}.$$

$$\text{Substituting values, } h = \frac{20^2 \times 10}{260 \times (1\frac{1}{2})^5};$$

$$\therefore h = \underline{2.025 \text{ feet.}}$$

(c) Head absorbed by $1\frac{1}{2}$ -inch plug cock.

$$\text{By Formula 64, } h = \frac{G^2 \times e}{d^4 \times 267}.$$

$$\text{Substituting values, } h = \frac{20^2 \times 1.4}{(1\frac{1}{2})^4 \times 267};$$

$$\therefore h = \underline{.414 \text{ feet.}}$$

Total head absorbed in discharging 20 gallons per minute
 $= (.467 + 2.025 + .414) = 2.906 \text{ feet.}$

As the actual head available is 7 feet, the discharge for this would be

$$\frac{20 \times \sqrt{7}}{\sqrt{2.906}} = 31.04 \text{ gallons per minute};$$

$$\therefore \text{Gallons discharged per hour} = \underline{31.04 \times 60 = 1862.4.}$$

If now we try to solve the problem by omitting the resistances (*a*) and (*c*), and ascertain the discharge directly by Formula 60,

$$\text{we have } G = \sqrt{\frac{d^5 \times f \times h}{l}}.$$

$$\text{Substituting values, } G = \sqrt{\frac{(1\frac{1}{2})^5 \times 260 \times 7}{10}};$$

$$\therefore G = 37.17 \text{ gallons per minute.}$$

And discharge per hour = $37.17 \times 60 = 2230.2$ gallons.

For this problem the two methods give a difference of $2230.2 - 1862.4 = 367.8$ gallons per hour.

The latter example clearly shows that when the discharging capacity of short pipes is required the total resistances should be taken into account, and this is especially necessary when the pipes are of large diameter.

When the length of a pipe, however, exceeds 400 times its diameter, it is as a rule sufficiently accurate to omit the small resistances. Formula 60 under such conditions will give the necessary discharge.

Suppose the diameter of a service pipe is required for filling a cistern in a given time, when the water in the main is under a known pressure as in Fig. 224. The type of ball-cock will affect the rate of discharge to a certain extent, but if a full-way cock is used, and the service pipe is of moderate length, the retardation offered by the tap when fully open may often be neglected. A ball-cock, of course, begins to close before the normal water-line is reached, unless special provision is made to prevent it. The pressure head above the point of delivery may be found by first converting the lbs. pressure per sq. inch into equivalent head, and afterwards deducting the vertical distance between the main (where the pressure is taken) and the point of discharge.

Example 35.—If a house is supplied on the intermittent system, find the size of pipe required to deliver 15 gallons per minute, when a pressure of 40 lb. per sq. inch is recorded where the service pipe joins the main. The length of the pipe is 150 feet, and the vertical distance between the main and point of discharge 45 feet. (See Fig. 224.)

To solve this problem it will be necessary to assume that the pressure is constant in the main.

For the conditions given the pressure head above the ball tap will equal $(40 \times 2.31) - 45 = 47.4$ feet.

Then by Formula 63,

$$d^5 = \frac{G^2 \times l}{f \times h}.$$

Assume the size required lies between 1 inch and $1\frac{1}{2}$ inch diameter in order to obtain a value for f , which according to Table VIII. will be 260.

Substituting values given,

$$d^5 = \frac{15^2 \times 150}{260 \times 47.4};$$

$$\therefore d^5 = 2.73.$$

On reference to Table IX. it will be found that the nearest size when raised to its 5th power, which satisfies 2.73, is $1\frac{1}{4}$ in. diameter;

$\therefore 1\frac{1}{4}$ inch is the diameter of pipe required.

The theoretical size lies between 1 inch and $1\frac{1}{4}$ inch diameter, but of course the

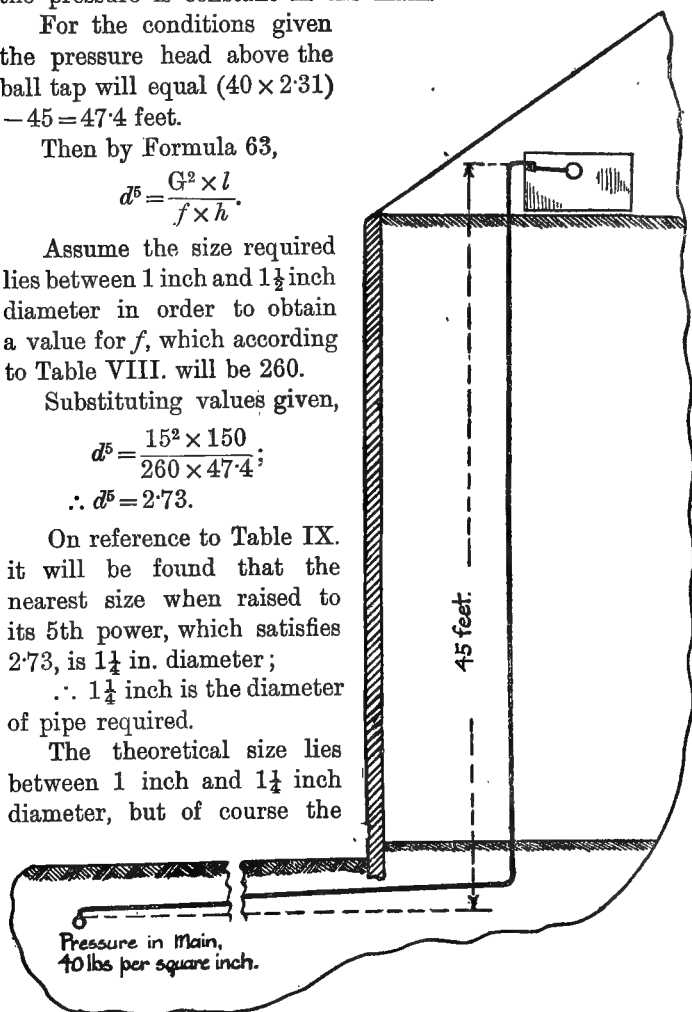


FIG. 224.—Flow of water through service pipes.

higher commercial size would be adopted, and this would compensate to a great extent for the retarding influence of the tap.

Another form of problem may now be attempted, where the pipes are arranged as in Fig. 225.

Example 36.—Determine the sizes of the pipes to deliver simultaneously 6 gallons per minute at C and 5 gallons per minute at D. The vertical distance between point C and the

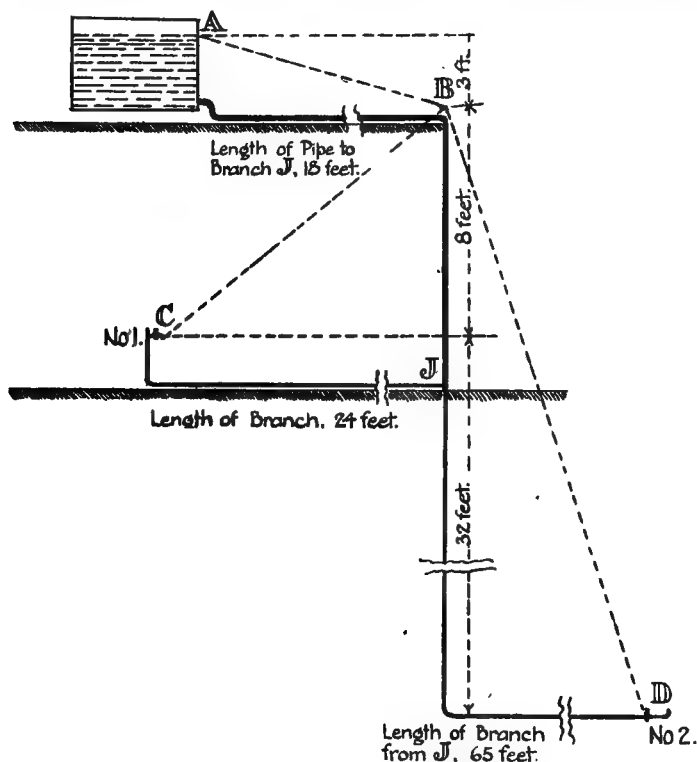


FIG. 225.—Flow of water from an overhead cistern.

average level of the water in the supply tank is 11 feet, and that between point D and the source of supply 43 feet, Branch No. 1 is 24 feet long, No. 2 branch 65 feet long, and the length of the draw-off pipe to J is 18 feet.

The first thing to consider is, that during the period of draw-off adequate pressure is maintained to properly supply both taps. To attain this end it is essential that the hydraulic

grade line for the main draw-off pipe shall not fall below the top of the bend at B. Suppose the drop of pressure is fixed at 3 feet, then the line AB will represent the hydraulic grade line for the main draw-off pipe. The hydraulic grade line for branch No. 1 is shown by the line from B to C, and that for branch No. 2 by the line from B to D. Having decided upon the hydraulic gradients, the sizes of the pipes can now be determined.

Size of Main Draw-off Pipe.—

The head available for the main draw-off is the vertical distance between A and B, Fig. 225, and this pipe will require to discharge $6 + 5 = 11$ gallons per minute. The length of pipe to branch J is given as 18 feet.

$$\text{By Formula 63, } d^5 = \frac{G^2 \times l}{f \times h}.$$

$$\text{Substituting values given, } d^5 = \frac{11^2 \times 18}{260 \times 3};$$

$$\therefore d^5 = 2.792.$$

From Table IX. we find that 2.792 lies between the 5th power of a 1-inch pipe and that of a $1\frac{1}{4}$ -inch pipe.

$$\therefore \text{size of main required} = \underline{1\frac{1}{4} \text{ diameter.}}$$

The value of f was assumed, and it is found to satisfy the answer obtained. Had it been too large or small this part of the problem would have required reworking.

Size of Branch No. 1.—

The head available for this, above the point of discharge, is the vertical distance between B and C.

$$\text{Then } d^5 = \frac{G^2 \times l}{f \times h}.$$

For trial value of f assume the pipe required does not exceed 1 inch diameter, when by Table VIII. $f = 210$.

$$\text{Substituting values, } d^5 = \frac{6^2 \times 24}{210 \times 8};$$

$$\therefore d^5 = .514.$$

Upon reference to Table IX. .514 lies between the 5th power of a $\frac{3}{4}$ -inch pipe and that of a 1-inch pipe;

$$\therefore \text{size of No. 1 branch} = \underline{1 \text{ inch diameter.}}$$

Size of Branch No. 2.—

The head above the draw-off tap on this branch is the vertical distance between B and D, Fig. 225.

$$\text{Then } d^5 = \frac{G^2 \times l}{f \times h}.$$

Assuming the diameter is less than 1 inch, then by Table VIII. $f = 210$.

$$\text{Substituting values, } d^5 = \frac{5^2 \times 65}{210 \times 40};$$

$$\therefore d^5 = .193.$$

In Table IX. it will be found that .193 lies between the 5th power of a $\frac{1}{2}$ -inch pipe and that of a $\frac{3}{4}$ inch pipe;

$$\therefore \text{size of branch No. 2} = \underline{\underline{\frac{3}{4} \text{ inch diameter}}}.$$

Collecting the sizes, we have—

Main supply pipe to J	.	.	.	1 $\frac{1}{4}$ inch diameter
No. 1 branch	.	.	.	1 " "
No. 2 "	.	.	.	$\frac{3}{4}$ " "

In each case the pipe is a trifle larger than necessary, so that each pipe will deliver rather more water than asked for in the question.

THICKNESS AND STRENGTH OF PIPES

The thickness of a cast-iron pipe for withstanding a given pressure is usually determined by some empirical formula, which provides a margin of safety for slight variations of thickness and other inequalities. So far as a lead pipe is concerned, its strength may be considered without much error to be directly proportional to its thickness, and inversely proportional to its internal diameter. The thickness of wrought iron and copper pipes is governed more by the form the joints take than by the internal pressure they are required to withstand. In the case of lead pipes a minimum thickness is necessary to resist crushing by external forces and to allow for the making of bends.

Formulae for Lead Pipes—

$$P = \frac{2 \times t \times S}{d} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (65)$$

$$S = \frac{P \times d}{2 \times t} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (66)$$

$$p = \frac{2 \times t \times S}{d \times F} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (67)$$

$$t = \frac{p \times d \times F}{2 \times S} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (68)$$

Where P = bursting pressure in lbs. per sq. inch.

„ p = safe working pressure in lbs. per sq. inch.

„ S = ultimate strength of metal per sq. inch.

„ F = factor of safety.

„ d = diameter of pipe in inches.

The factor of safety varies from 5 to 10, and these values indicate that the maximum safe working pressures are fixed at 5 to 10 times less than those which produce fracture.

TABLE XI.**AVERAGE TENSILE STRENGTH OF METALS PER SQUARE INCH**

Copper . .	31,000 lb.	Wrought iron .	50,000 lb.
Cast iron . .	18,000 „	Lead . . .	2,600 „
Cast steel . .	62,000 „	Tin . . .	4,500 „

The formulæ for lead pipes may be checked by the following tests, which were carried out for the writer:—

TESTS ON LEAD PIPES

Test No.	Bore of pipe.	External diameter.	Weight per lineal yard.	Thickness walls of pipe.	Bursting pressure per sq. inch.
1	$\frac{1}{2}$ inch.	·92 inch.	7 lb.	·21 inch.	1960 lb.
2	$\frac{3}{4}$ „	1·23 „	11 „	·24 „	1500 „
3	1 „	1·54 „	16 „	·27 „	1340 „

Using the results of these tests for obtaining the ultimate strength of lead, we have by Formula 66,

$$S = \frac{P \times d}{2 \times t}.$$

Substituting values from Test No. 1,

$$S = \frac{1960 \times \frac{1}{2}}{2 \times .21};$$

$$\therefore S = \underline{2333 \text{ lb. per sq. inch.}}$$

Substituting values from Test No. 2,

$$S = \frac{1500 \times \frac{3}{4}}{2 \times .24};$$

$$\therefore S = \underline{2343 \text{ lb. per sq. inch.}}$$

Substituting values from Test No. 3,

$$S = \frac{1340 \times 1}{2 \times .27};$$

$$\therefore S = \underline{2481 \text{ lb. per sq. inch.}}$$

For each test the ultimate strength of lead has a different value, but this is chiefly due to the fact that lead pipes are seldom perfectly true in section, especially when the pipes are of small bore. The strength of a pipe of course is only equal to that of its weakest side. In Table XI. the strength of lead is given at 2600 lb. per sq. inch. Test No. 1 gives within 11 per cent. of that value, and Test No. 3 within 5 per cent. From these results we may infer that a higher factor of safety is necessary for small bore pipes than for those of larger diameter.

Example 37.—Find the maximum safe working pressure for a $\frac{1}{2}$ -inch lead pipe which weighs 7 lb. per yard, when a factor of safety of 8 is adopted.

$$\text{By Formula 67, } p = \frac{2 \times t \times s}{d \times F}.$$

The value of t in the table of tests = .21,
whilst s in Table XI. = 2600.

Including these values and the others given,

$$p = \frac{2 \times .21 \times 2600}{\frac{1}{2} \times 8};$$

$$\therefore p = \underline{273 \text{ lb. per sq. inch.}}$$

Example 38.—Determine the thickness for a $1\frac{1}{2}$ -inch diameter lead pipe which is to be subjected to a maximum pressure of 45 lb. per sq. inch, when the factor of safety 6 is adopted.

$$\text{Using Formula 68, } t = \frac{p \times d \times F}{2 \times s}.$$

$$\text{Substituting values, } t = \frac{45 \times 1\frac{1}{2} \times 6}{2 \times 2600};$$

$$\therefore t = \underline{.078 \text{ inch thick.}}$$

Although a pipe of the latter thickness would withstand the internal pressure, it would be far too thin for a water pipe, its weight per lineal yard being a little less than $5\frac{1}{2}$ lb. From Example 38 we see that Formula 68 is not suitable for ascertaining the thickness of pipes for withstanding either medium or low pressures. For example, a $1\frac{1}{2}$ -inch lead waste pipe which weighs 12 lb. per yard has a thickness of .156 inch, and with a factor of safety 6 would be capable of withstanding a pressure of 90 lb. per sq. inch.

Formula for Cast-Iron Pipes—

The thickness of cast-iron pipes up to 9 inches diameter can be determined by the formula below.

$$t = [\{ (.00014 \times d) \times (p + 50) \} + .27] \quad . \quad . \quad (69)$$

Where t = thickness of metal in inches.

„ p = water pressure in lbs. per sq. inch.

„ d = diameter of pipe in inches.

Example 39.—Find the thickness of a 6-inch diameter cast-iron pipe which is subjected to a pressure of 150 lb. per sq. inch.

$$\text{By Formula 69, } t = [\{ (.00014 \times d) \times (p + 50) \} + .27].$$

$$\text{Substituting values, } t = [\{ (.00014 \times 6) \times (150 + 50) \} + .27],$$

$$t = [(.00084 \times 200) + .27];$$

$$\therefore t = \underline{.438, \text{ or say } \frac{7}{16} \text{ inch thick.}}$$

CHAPTER XIII

DOMESTIC HOT WATER SUPPLY

Movement of Heat.—Heat moves in three ways: (*a*) by conduction; (*b*) by convection; (*c*) by radiation. To heat water in an apparatus the first and second forms of heat motion come into operation. When the surfaces of a boiler are exposed to the action of heat, a certain amount of the latter is transmitted through the plates. In other words, heat is conducted through the metal walls from the fire to the water side of a boiler, and, in turn, heat is absorbed by the water in contact with the heated surfaces. The transference of heat from receptacle to receptacle which contains water is accomplished by convection, when suitable passages are provided through which the water can circulate.

Circulation of Water.—Movement, or circulation, of the innumerable particles of which water consists takes place as soon as they differ in weight, the more highly heated and lighter particles being displaced by those of greater density.

In order for water to freely circulate between two receptacles, such as a boiler and a tank, two separate paths are essential. One path is provided through which the heated particles escape after being heated, and the other returns the cooled particles to the source of heat.

The Tank System.—Fig. 226, although not often installed, possesses one or two favourable points. In the first place the position of the stored hot water admits of a cheap form of tank being used, and this, accordingly, reduces the cost of a completed system. Instead of a cylindrical tank, either a square or rectangular form may be adopted. Another advantage possessed by the *tank system*, is that a free outflow of water can be obtained at the highest draw-off taps, on

account of the water being withdrawn directly from the overhead tank, and owing to the comparatively short lengths of pipe through which it has to flow.

The *tank system*, however, has drawbacks. The tank could be emptied by any of the draw-off taps should the supply to

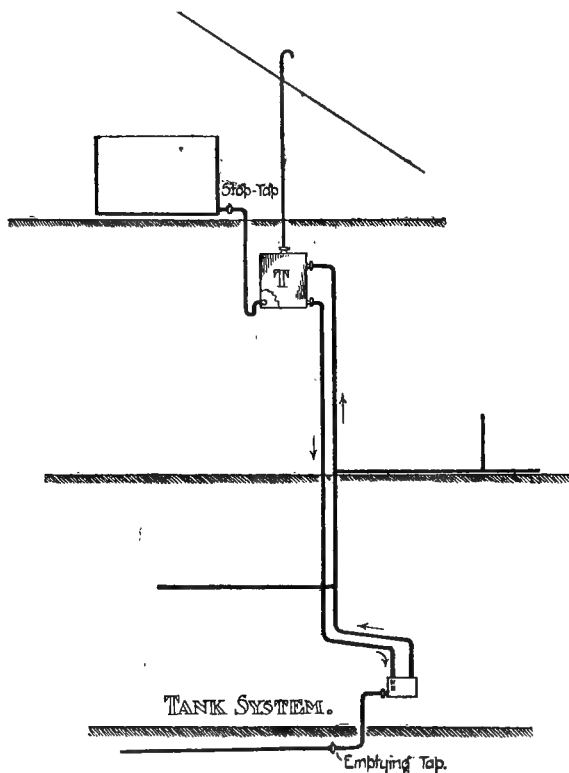


FIG. 226.

the feed cistern fail, and when water is withdrawn at a tap a mixture of hot and colder water is frequently obtained. The latter is a bad feature in connection with the tank system, for the resultant temperature at the point of escape may be considerably less than that of the water in the tank. Of course, when the draw-off first begins the water which oc-

cupies the upper part of the boiler will be at a higher temperature than that in the upper part of the tank, and if only a small volume is withdrawn the hottest water may issue at the point of escape. On the other hand, when larger volumes are required the heated water in the boiler is soon replaced with colder water, and this flows to the point of draw-off and mixes with that from the overhead tank.

With regard to the volume of the water which will travel by each path, this will depend entirely upon the resistance offered, the greater volume naturally flowing by the route which offers the least obstruction. . As a rule the taps at the higher levels will discharge a greater percentage of hot water directly from the tank than taps at lower points. In Fig. 226 the flow and return circulating pipes are shown to take a very favourable course between the boiler and the tank, but in practice the course is often more circuitous than shown. The length of the circulation pipes retards the movement of the water, for as a rule these pipes are only of small bore.

Details of Tank Systems.—It will be observed in Fig. 226 that the draw-off branches are only taken from the flow-pipe, and if the best results which this system is capable of yielding are to be obtained, the flow-pipe will require to terminate at a fairly high point in the tank. In some cases a separate draw-off pipe is adopted which is joined half-way up the tank. With regard to the cold supply to tank T, it will improve matters, where the relative positions of the pipes are as shown, if the water is deflected downwards or sideways when it enters the tank by means of an elbow or tee. This arrangement prevents the cold water upon entering the tank from taking a direct course to the return pipe when hot water is being withdrawn.

The connections to the boiler are shown at the top, the return being continued by means of a tube to near the bottom of the boiler. It is not practicable in every case to make the boiler connections in the position shown, and it is often necessary to either join the pipes at the side or at the back.

High and low connections to a boiler are not essential to make the water circulate, but they define the course the water should take

Although high and low connections with boilers are generally made, it is not uncommon to find that reversed circulations occur. As a general rule, it will be found when an intended flow-pipe acts as a return, and *vice versa*, that some form of retardation has been introduced in connection with the flow-pipe. The flow-pipe connection should provide as free a passage as practicable for the escape of the heated water, and when the flow-pipe is either joined at the side or at the back of a boiler, the length of the horizontal pipe in the immediate neighbourhood of the boiler should be reduced to a minimum. If a portion of a flow-pipe must be horizontally arranged, this should be introduced if possible above, and not on a level with, a boiler.

Where a tank system is adopted, and it is deemed necessary to shorten the lengths of the dead branches in order that hot water may be readily obtained after the opening of a tap, the piping may be arranged as in Fig. 227. The branch circuit should be kept as short as possible, and the pipes should have a gradual rise towards the tank. To enable water to circulate through the branch in the direction indicated by the darts, a stop tap *s* should be introduced immediately above the branch at B. It is only essential for a small portion of the water to circulate through the secondary circuit, and this can be adjusted by means of the stop tap S.

Cylinder System.—For heating water for domestic purposes the cylinder system is the more generally adopted. It chiefly differs from the tank system in the following respects :—

- (a) A cylindrical tank takes the place of the square or rectangular one, as a circular shape is better suited for resisting internal pressure.
- (b) Shorter circulation pipes are employed on account of the cylinder being located nearer to the boiler.
- (c) The cylinder is arranged to remain full or partially charged when the cold supply fails.

In Fig. 228 a cylinder system is shown which is suitable for a small dwelling, and all the connections are arranged to give good results. The air or expansion pipe is shown to terminate above the roof, but when in the immediate neighbourhood of a supply tank it may be turned over so as to

discharge into it as shown by dotted lines. There is not often any objection to the latter method, excepting where the temperature of the cold water is liable to be appreciably raised, and when cisterns are fixed in positions where the free escape of steam would be objectionable.

All draw-off branches in a small cylinder system are joined to the air-pipe (excepting special cases), and it is desirable that

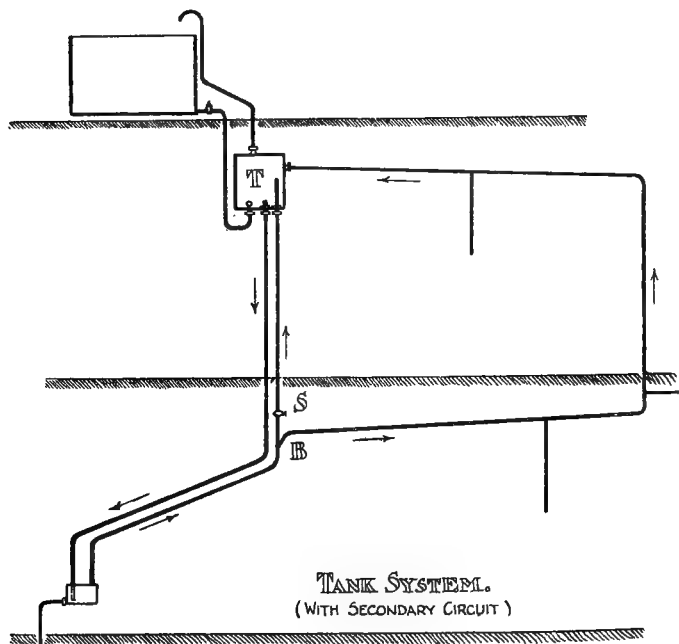


FIG. 227.

these connections be located well below the bottom of the cold supply cistern, in order to prevent air entering and being discharged with the water when draw-off taps are opened.

To enable a system to be emptied of water, a pipe is frequently connected with the boiler, as in Fig. 228, the free end terminating at any suitable point. A stop tap C should be provided on the cold supply pipe so that the water can be turned on and off as required.

On account of the diversity of views which prevail as

to how the various connections with a cylinder system should be made, it may be well at this point to discuss some of the methods of arranging the pipes, and to point out any merit or demerit they possess.

In Fig. 229 the cold supply is shown joined directly with the boiler, this method being largely adopted in certain

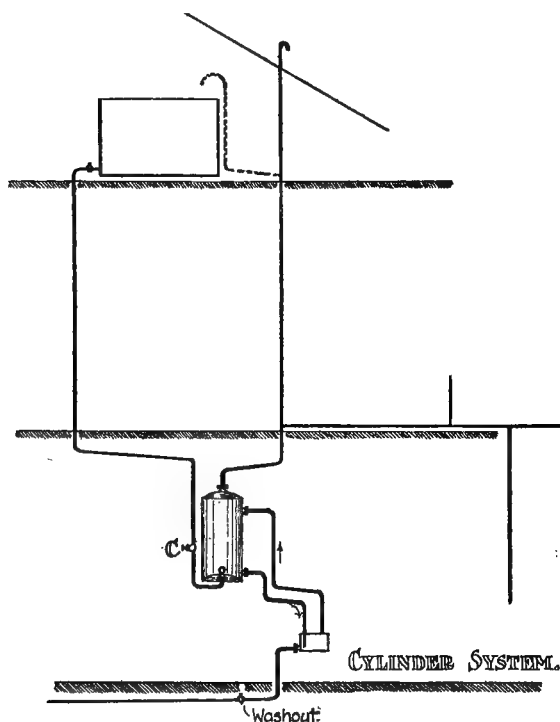


FIG. 228.

districts. In this case the principal thing to consider is, the final temperature of the water when discharged at any point when compared with that in the cylindrical tank. When a tap is opened, water will flow to the point of escape from any available source, and when the pipes are arranged as in Fig. 229, the cold water upon entering the boiler can flow to the cylinder through either the flow or return pipe. If only

a comparatively small volume of water is withdrawn at a time, the cold supply connection as arranged will answer fairly well; when, however, larger volumes are withdrawn the hot water in the boiler is soon displaced, and cold water passes through the flow pipe and mixes with the heated water at the top of the cylinder. Should the flow connection be made immediately above the return, the water in the upper part of the cylinder may not be unduly cooled during the period of withdrawal. It is, however, generally desirable for a

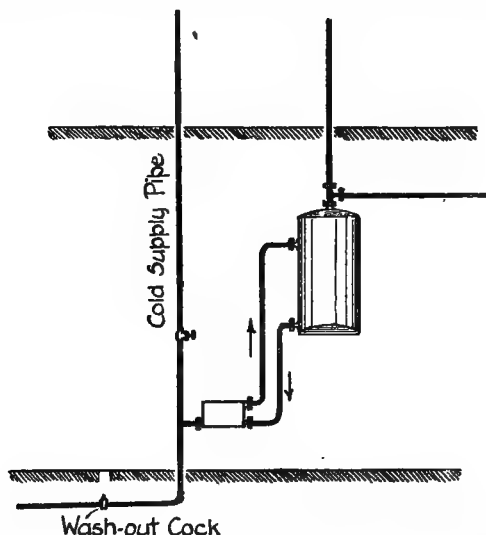


FIG. 229.—Cylinder system where cold water supply joins directly with boiler.

flow-pipe to be connected at a high point of the cylinder, as this allows a limited volume of very hot water to be quickly obtained after a fire is first lighted. If, on the other hand, the flow connection is made at a low point, then the heat transmitted from the boiler in a given time is diffused throughout a greater mass of water, and consequently it is raised through a smaller range of temperature.

No fault can be found with the connections in Fig. 229 so far as the heating of the water is concerned, but the fault occurs when a moderate volume of water is withdrawn.

It is frequently contended that cold water should not directly enter a boiler as in Fig. 229, on account of the latter being subjected to great variations of temperature, and, in consequence, a greater amount of strain. This point, however, so far as range boilers are concerned, is not of much importance, for in practice the life of a boiler does not appear to be affected by any particular arrangement of the cold supply.

The principal advantage offered by joining the cold supply to the cylinder, is that unnecessary mixing of hot and cold water can be prevented when water is withdrawn. When the cold supply is joined, as in Fig. 228, the entering water is well diffused over the lower portion of the cylinder, and the upper and hotter water is more nearly uniformly displaced.

In Fig. 230 the flow connection to the cylinder is shown joined at a low point, and a by-pass is provided between the flow and the air-pipe. For a simple system, a by-pass offers no special advantage, its use being only intended to convey a portion of the hottest

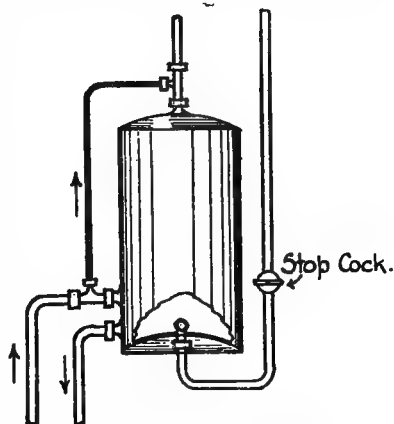


FIG. 230.—Cylinder system with by-pass between flow and air pipe.

water directly to the top of the cylinder. As a rule this can be better accomplished by joining the flow-pipe directly at a higher point.

Secondary Circuits.—Although for the smallest installations secondary circuits are not required, they are desirable in large buildings to avoid long dead branches, and to permit of hot water being withdrawn immediately after opening a tap. A secondary circuit is shown in Fig. 231, and the lower end is joined about 6 inches below the top of the cylinder. In order for water to circulate through the secondary circuit, the latter must be arranged that air cannot accumulate in it. It is not essential that a circuit should fall from the main air

or expansion pipe, provided that air can freely escape at the highest point. When a tap is opened on a system which is arranged like Fig. 231, water can flow to the point of escape by either of two routes. For this reason it is desirable

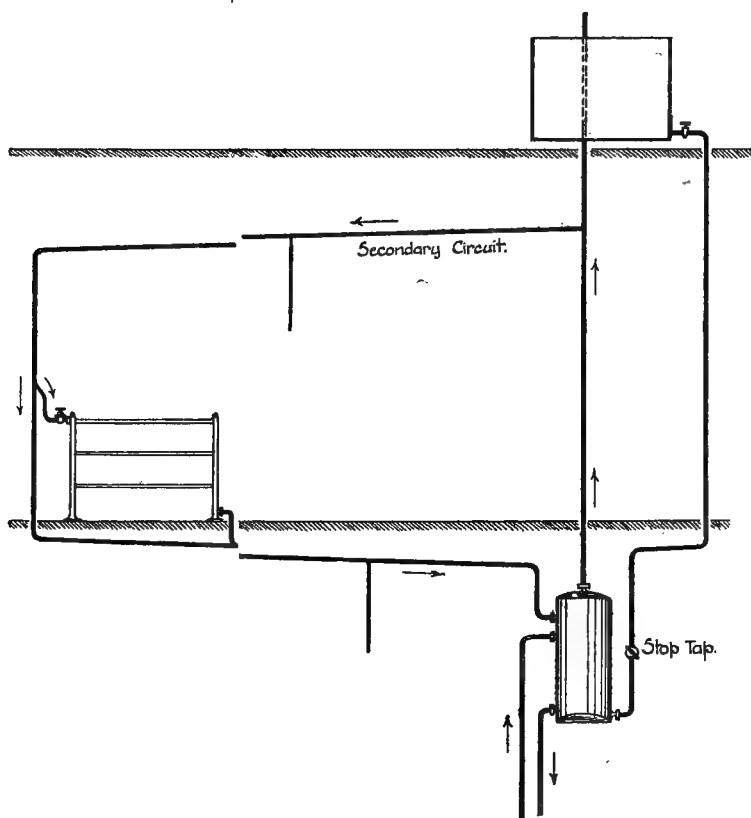


FIG 231.—Cylinder system with secondary circuit.

that the lower end of the secondary circuit be joined to the upper part of the cylinder, in order that the hottest water available may be withdrawn, irrespective of the path the greater volume may take.

Occasionally a towel-rail, coil, or small radiator is joined to a secondary return, and either may be heated satisfactorily

provided the boiler is of ample power. Should a towel-rail be fixed as in Fig. 231, the flow connection may be taken from the vertical pipe, whilst the return from the rail may be joined to the horizontal pipe. In this case an air-pipe or cock is not essential, as the air can escape from the rail through the higher connection. If the flow-pipe, however, should join at the bottom of the rail, then special provision for the escape of air would be necessary.

When a coil or radiator is of more or less considerable distance from the draw-off taps, it may be desirable to provide a separate circuit for it. Each case, however, should be considered on its own merits, and when the laws which govern the movement of water through pipes are thoroughly understood there is no difficulty in arranging a circuit to give good results. If, for example, it is proposed to fix a radiator in a room adjoining a kitchen, the former in many cases may be heated from the kitchen range or other fire when a suitable boiler is used. Assuming that a radiator is fixed on the floor as in Fig. 232, it will be necessary for the water to circulate below the boiler, but this will present no difficulty if the flow-pipe is taken from a position which will give a good circulating head. In Fig. 232 a separate connection is taken from the boiler to heat the radiator, and this is generally the most satisfactory course to adopt. The circulating head is obtained by rising the flow-pipe several feet above the boiler, and from the highest point of the circuit the return passes to the radiator, and thence to the boiler. An air-pipe will, of course, be necessary at the head of the circuit, and this will require to terminate above the level of the water in the supply cistern.

With regard to the size of circuit for supplying a radiator, this as a rule should not be less than $1\frac{1}{4}$ inches diameter, on account of the resistance offered to the circulation by the length of the pipe and the column of cooled water in the pipe EF. To aid the circulation the horizontal pipe ED should be as short as practicable, although, so far as the horizontal pipe BC is concerned a greater length may be advantageous, in order that the water may be further cooled, and so give a greater average density in the descending column

CD. The flow and return on the left side of Fig. 232 may join with a cylinder in the ordinary manner.

In a small dwelling the cylinder is sometimes located in a bathroom, instead of near to the kitchen range; this arrangement may prove advantageous in many cases, as the heat given out by the cylinder may be utilised for airing linen or for keeping a bathroom warm in cold weather. A cylinder, however, when fixed some distance from a range presents a few drawbacks which may be enumerated as follows:—

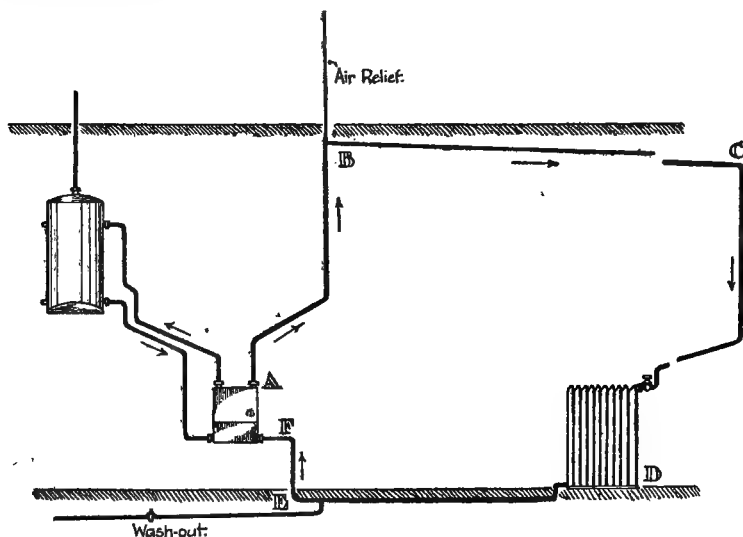


FIG. 232.—Cylinder system with separate circuit for heating a radiator.

- (a) Longer circulation pipes are necessary.
- (b) The possibility of circulating pipes being exposed to a draught when laid beneath floors, and the risk of their being choked with ice in frosty weather.
- (c) Long dead branches may be produced.

So far as the airing of linen is concerned, this can be done by a coil of pipe when joined to a secondary return, but this adds to the cost of the installation.

The objection to longer circulation pipes can be partially

overcome by increasing their size, but this is frequently overlooked.

A typical example of a cylinder when fixed on the first floor of a building is shown in Fig. 233. For the conditions shown it would be useless to join the secondary return just below the top of the cylinder as indicated by the dotted line L, for water would lie stagnant in the pipe excepting when a draw-off tap was opened. To cause the water to circulate through an arrangement like that shown in Fig. 233, the lower end of the secondary circuit may be joined with the return to the boiler. By means of the non-return valve the water is

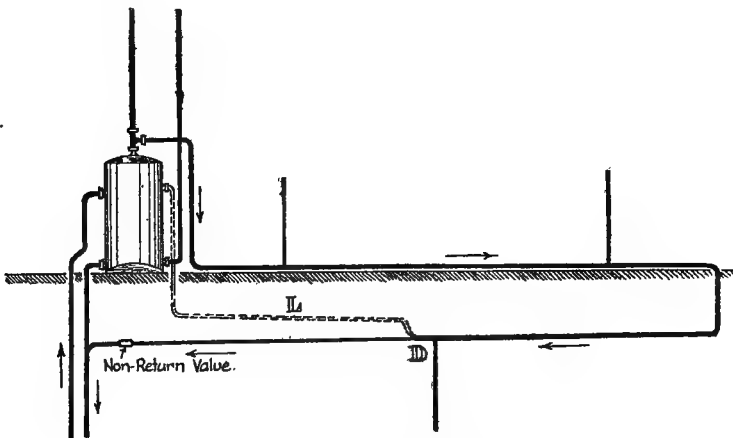


FIG. 232.—Cylinder system with secondary circuit.

prevented from flowing from the bottom of the cylinder when a draw-off tap is opened. As check valves are liable to get out of order, it is desirable to prevent as far as possible any ill-effect arising from this cause. Should, however, a valve get out of order, the trouble during the period of draw-off would be minimised if the size of the circuit were reduced after passing the last draw-off branch D, as in Fig. 233.

To reduce the size of the secondary circuit before the non-return valve is reached would retard the circulation of the water, but that may not be of paramount importance for the case shown. The object of a secondary return is simply to

reduce the length of dead branches, and it matters little whether the water in the secondary return is kept in a heated state by either a quick or a slow rate of circulation. Further, if it is deemed desirable to increase the circulating head in the secondary return, the latter may join the main return nearer to the boiler.

A suitable form of non-return valve for fixing on a horizontal pipe is given in Fig. 234, but the flap should be made as light as possible. Other forms may be obtained for vertical pipes, but the latter unduly retard the circulation and should not be used.

In tenement dwellings, where each flat is provided with a

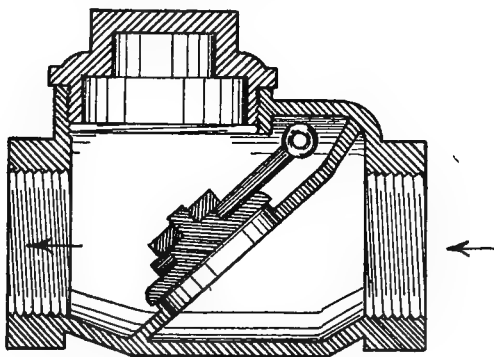


FIG. 234.—Reflux or non-return valve.

separate hot water service, the cold water supply from one overhead cistern may be utilised for a number of cylinders, or each system may have its own cold supply tank, as in Fig. 235. When the latter method is adopted, one main air-pipe is generally employed into which the air-pipe from each cylinder is joined. The junction with the main air-pipe should not be much less than 9 inches above the highest water level of the cold supply tank, in order to prevent the overflow of hot water through expansion. The top of the main air-pipe should terminate above the roof or other suitable place, and the bottom of the air-pipe may terminate at any suitable point beneath the lowest cylinder.

The draw-off pipe A, Fig. 235, on account of its being only a

short distance below the bottom of the supply tank, often allows air to be discharged with the water, which issues in an irregular or jerky manner at the point of escape.

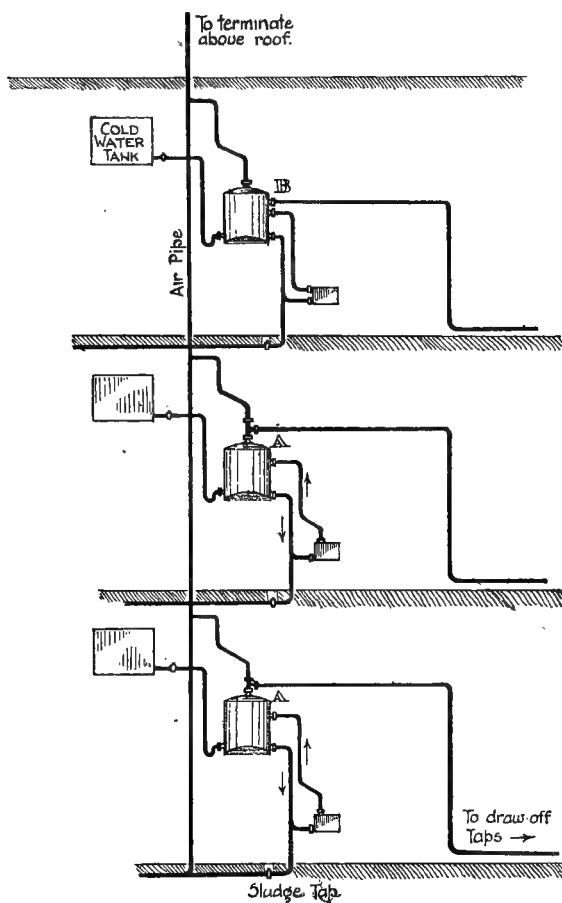


FIG. 235.—Cylinder system for tenement buildings where each flat is provided with a cold-water supply tank.

To prevent air gaining access to a draw-off branch, either the pipes must be graded as regards their size, or the principal draw-off pipe may be joined about 6 inches below the top of the cylinder, as at B, Fig. 235.

Square or rectangular tanks may be used in lieu of cylindrical ones for an arrangement like Fig. 235, as the pressure upon them is small.

The more general method of arranging the hot water

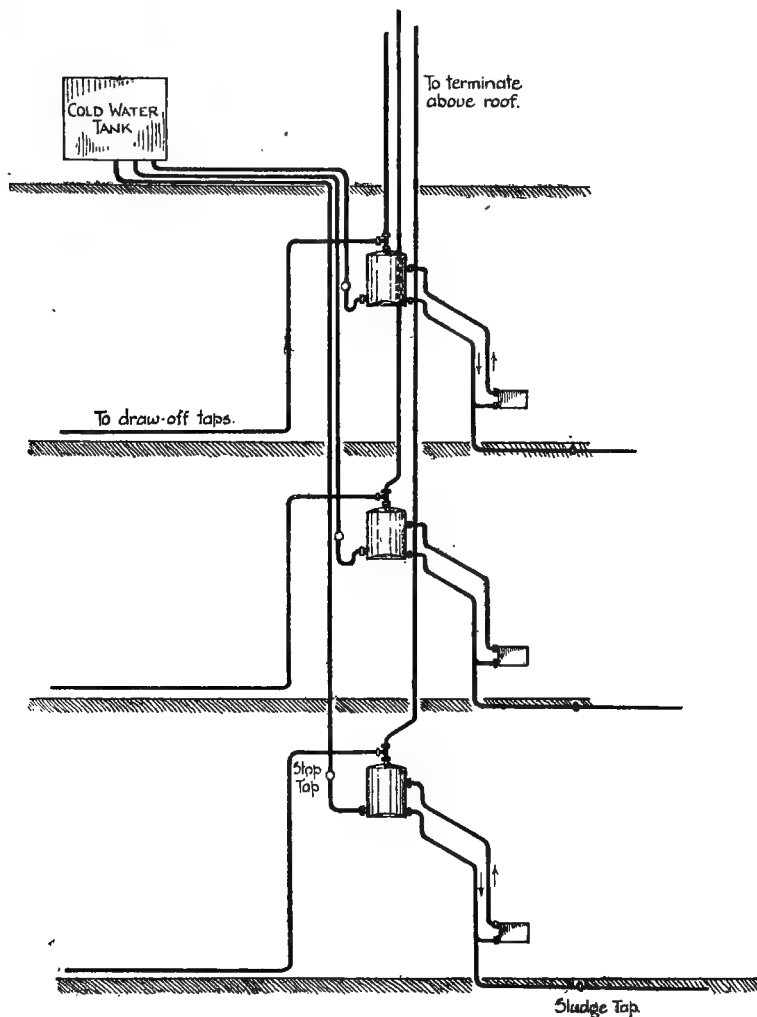


FIG. 236.—Cylinder system for tenement buildings where cylinders are supplied from one overhead tank.

supply for tenement dwellings is shown in Fig. 236, where a separate supply pipe to each cylinder is taken from an overhead cistern. This arrangement has the advantage of giving a quicker outflow of water at the draw-off taps on the lower flats, on account of the additional pressure to which they are subjected. For the highest flats, the pipes may be treated as before described, to prevent air flowing along with water through the draw-off branches.

It is not an uncommon thing in old tenement buildings to find a similar arrangement to that given in Fig. 237. This is a case of scamped work, and it often proves very disagreeable for the dweller in the top flat. It will be observed that the cylinders on the different floors are supplied by one common pipe, and although the branch connections may be made as shown, hot water is frequently withdrawn from the upper cylinders by the occupiers of the lower flats. This condition readily occurs when the horizontal pipe AB is rather long, and where the supply and draw-off pipes are of equal bore.

When the arrangement in Fig. 237 is considered, it will be evident that the horizontal length AB is not capable of discharging so large a volume as the vertical pipe BC, and in consequence there is a tendency for a partial vacuum to be created in the vertical pipe, when water will be siphoned from the cylinders above.

Systems for Large Buildings.—When dealing with large buildings, the general design of a system for heating water will largely depend upon the magnitude of the system, the height of the building, upon the positions of the draw-off taps, and whether steam is available or not. The heating capacity of range boilers is of course limited, and although they are very convenient for small installations, they are not suitable for heating large volumes of water.

Steam, when available, can advantageously be utilised for heating large volumes of water in a limited time, but it is not economical to specially generate it for this purpose.

Both the cylinder and cylinder-tank systems are commonly adopted for large buildings, the latter system being suitable where draw-off taps are located at high levels.

Two or more secondary circuits may be essential in a large

system, and the boiler should be located as centrally as possible in order to keep the circuits within a reasonable length. In

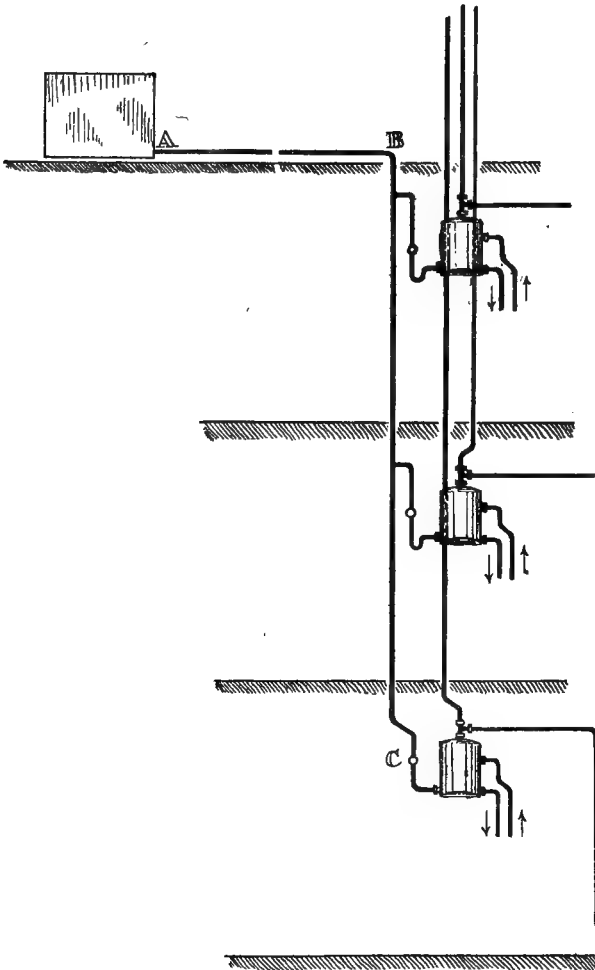


FIG. 237.—Defective arrangement of cold supply pipes to cylinders.

certain cases, where large volumes of hot water are required about the same time both on an upper and a lower floor, it may be desirable to provide two distinct systems of supply.

Separate systems may also be desirable for supplying isolated groups of fittings in large buildings.

Cylinder-Tank System.—As the term implies, this is a combination of the cylinder and the tank systems, and it is sometimes claimed that the combined arrangement retains the principal merits of both systems whilst eliminating their drawbacks. This, however, depends on how a system is designed. The pipes may be arranged in various ways, a good method being given in Fig. 238, provided the pipes are properly sized. The cylindrical tank is fixed as near to the source of heat as possible, whilst the top of the rectangular tank is located about level with the bottom of the cold water supply cistern.

In Fig. 238 one secondary circuit is shown, by taking the pipe from the top of the cylinder and joining it near to the bottom of the rectangular tank, and by taking it from the opposite side back to the cylinder. From the secondary circuit the draw-off branches are taken.

In order that circulation may take place as indicated by the darts, the secondary flow pipe should offer the least resistance; in other words, this should take the shortest route and contain the least number of bends.

When a draw-off tap is opened at a high point, say at P, Fig. 238, water is free to flow directly from the overhead tank, and also from the cylinder. In any case a free discharge at P is assured, whereas, with a cylinder system, the whole of the water before being withdrawn must pass to the cylinder before it can escape at a higher point. Where pipes are of considerable length, and the point of draw-off at a high level, the outflow of water from a cylinder system may be far from satisfactory.

With regard to the comparative sizes of cylindrical and rectangular tanks, that is a matter which can only be settled when the whole circumstances of any particular case are taken into account. For example, assuming the larger volume of hot water is required at a high level, then, as a rule, the upper tank should have the larger capacity. On the other hand, where the greater demand for hot water is made at a lower point, the cylinder may require to have the larger capacity. In each case, however, the sizes and general arrangement of

the pipes will require to be taken into account. Under favourable conditions, where there is free circulation between the cylindrical and the upper tank, the hottest water will be

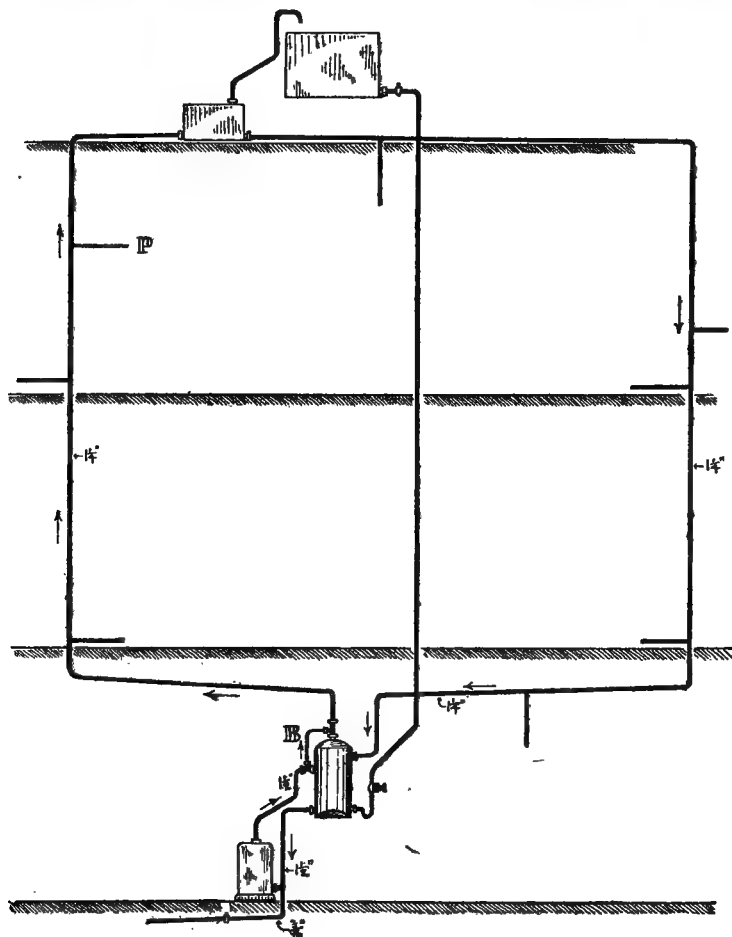


FIG. 238.—Cylinder-tank system.

stored in the latter; if, however, the circulation in the secondary circuit is retarded by long stretches of nearly horizontal pipe, which may be of small bore, then the hottest water will accumulate and remain in the lower tank.

A by-pass B is shown in Fig. 238 between the primary and the secondary flow pipes; this may be an advantage in certain cases, as a portion of the hottest water may be delivered directly from the boiler to the upper tank. When the secondary circuit joins the upper tank in the manner shown, the latter should be as shallow as practicable, so as to limit the difference in temperature between the highest and lowest particles of water.

It may occasionally be necessary to arrange two or more circuits, as in Fig. 239, when a building is large and the fittings are somewhat scattered. Each secondary flow may be separately joined with the cylinder, and although this is not absolutely essential, it is generally desirable, as each circuit can be independently and readily controlled.

Much more care is necessary when designing a cylinder-tank system, than is the case with a cylinder system, if good results are to be obtained. Suppose, for example, a large volume of water is withdrawn through branch M, in the right hand circuit of Fig. 239, the greater volume of water would flow from the lower tank; in fact, it is quite possible when the general design is as shown, and when the horizontal distance between the upper hot-water tank and the vertical part of the secondary return is more or less considerable, to draw warm water through M when much hotter water is stored in the overhead tank. The reason for this, of course, would be due to the lower part of the secondary return offering much less resistance to the flow of water to the point of escape.

The position of the overhead hot-water tank is an important factor in a cylinder-tank system. In the circuit on the left side of Fig. 239 the overhead hot-water tank is located near to the vertical return, whilst on the right circuit it is placed near to the vertical flow pipe. Assuming water is withdrawn at point T, the advantage of a hot-water tank immediately overhead is at once apparent, as the whole of the head between the point of draw-off and the water in the tank is available for forcing water to the point of escape.

A branch between the secondary flow and return on the top floor may in many cases be an advantage, as hot water may be directly delivered from either tank to points P and T in Fig. 239

When, however, a branch between a secondary flow and return is provided, care is necessary in its arrangement in order that the heating of the water is not impaired by short circuiting taking place.

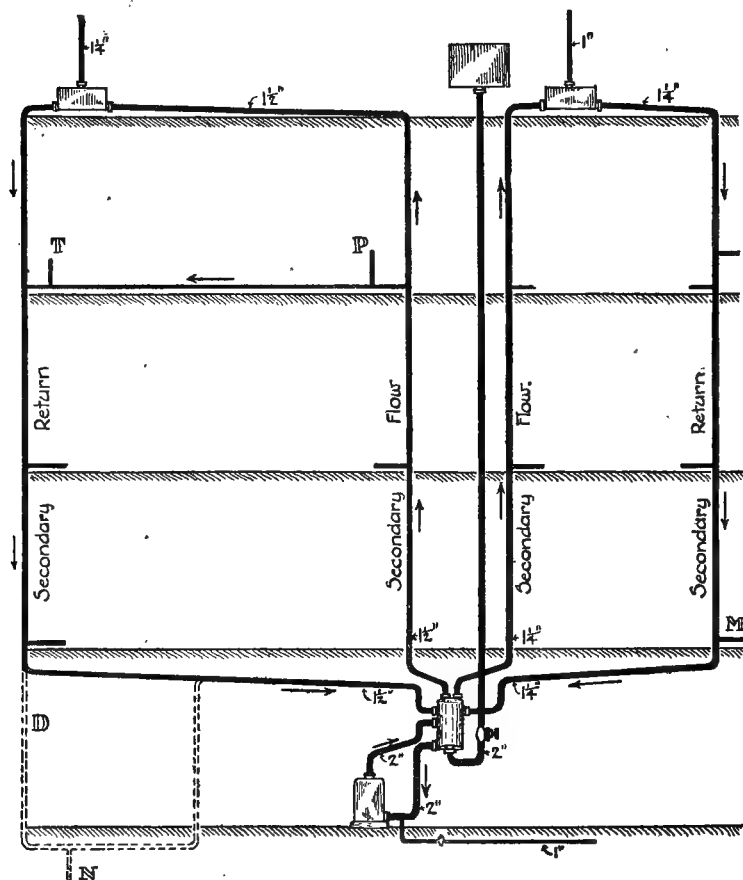


FIG. 239.—Cylinder-tank system with two secondary circuits.

If it should be desired to have hot water readily available at a point say N, Fig. 239, a branch circuit should be provided as shown by dotted lines at D. In this case the dipping of a main secondary circuit would be prejudicial to the heating of the water in the upper tank.

In a cylinder-tank system it is not only a question of whether water will circulate along a given route, but whether the circulation will be sufficiently active to make a system efficient.

Another point of importance is, that when a large volume of water is to be withdrawn at any one time from the secondary return, the connection with the lower tank should be as high as practicable. For a given capacity of cylinder the diameter should also be small, in order that the tank may be fairly high.

Boilers for Heating Water.—Speaking generally, boilers for heating water are either classed as range or as independent boilers, the former including those which are fixed in open fire-grates.

Boilers take many forms, and are made in cast-iron, wrought-iron, and copper. The choice of a metal, except for the cheapest work, is usually controlled by the character of the water to be used.

Soft waters readily attack iron, forming ferric oxide or rust, and as the latter is also objectionable on account of its imparting redness to the water, copper boilers should be adopted in soft water districts. On the other hand, when water contains temporary hardness, iron boilers are very suitable and have the advantage of a low initial cost.

Water containing temporary hardness soon deposits a film of carbonate of lime on the boiler surfaces and thus protects the metal beneath. Large deposits are of course injurious.

Cast-iron boilers, although largely used in some districts, are not suitable for range boilers, unless adequate precautions are taken to prevent a possible explosion taking place. As a rule, however, where cast-iron boilers are used no special provision is made to render them safe, on account of the additional expense involved.

Fig. 240 gives a common form of wrought-iron range boiler. These are frequently shallow and not more than about 6 inches deep. From the toe to the back they should be as long as possible, in order to expose a large surface to the fire and to the heated products of combustion. The top surface of a boiler is of little or no use for transmitting heat, on account of the soot which gathers there, and also to the slow

rate at which heat is conducted by water in a downward direction. The front and bottom surface of a plain boiler are the most important and absorb the greatest amount of heat per unit area of surface.

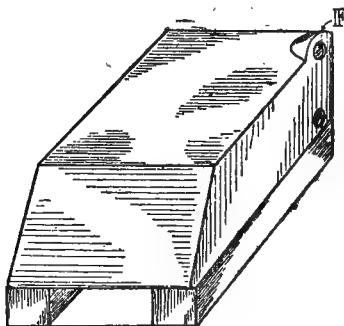


FIG. 240.—Range boiler.

Frequently range boilers are arched as Fig. 241, but with regard to their capacity for transmitting heat they are mostly overrated. As a rule, there is little difference between the arched and the plain type so far as their heating power is concerned. In certain ranges, arched boilers are necessary on

account of the limited depth of the fire-box.

In Fig. 242 a block boiler is shown in position. It will be observed that the bottom of the flue beneath the boiler is raised above the grate, and this is desirable, as it prevents, to a great extent, the choking of the flue with ashes which are often allowed to accumulate on the grate. For a boiler to absorb a fair amount of heat the bottom flue *e*, Fig. 242, should not be more than 3 inches deep, whilst its width should be proportioned to the size of the fire. The flue over the top of the boiler should be shallow, and, as a rule, not more than $1\frac{1}{2}$ inches deep. The top of the boiler, for reasons previously stated, is practically useless for transmitting heat, but the top flue renders the front more effective, as it can be enveloped with flame when a range is closed.

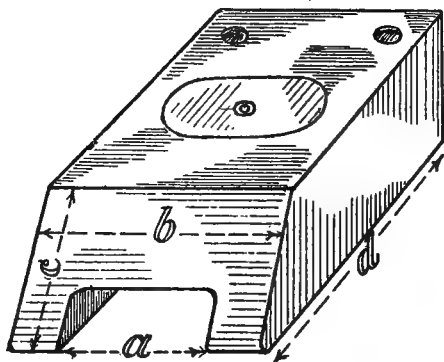


FIG. 241.—Arched range boiler.

A defective method of fixing a range boiler is that, where

the bottom flue is made level with the fire-grate. This allows the flue to get readily choked, and where the fire-grate also extends a short distance under a boiler, cold air enters directly through the grate, cools the products of combustion, and lowers the efficiency of the boiler.

When it is necessary to join circulating pipes at the side or back of a boiler, the point where the flow connection is

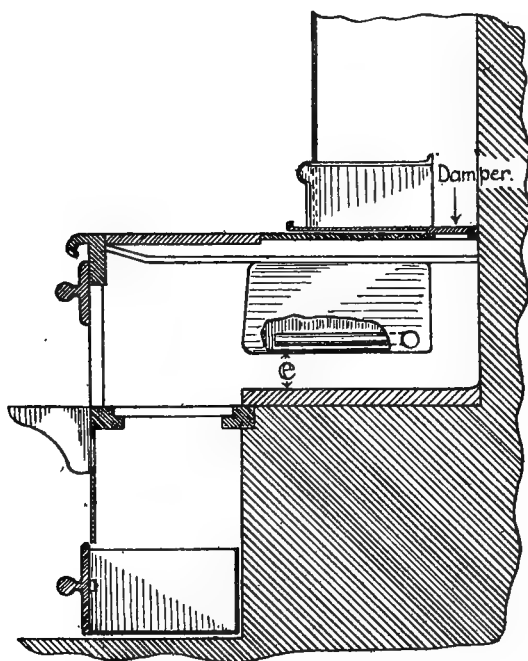


FIG. 242.—Illustration showing flues round boiler.

made should be raised as at F, Fig. 240, in order to prevent air being confined at that point. The same precaution holds good when the circulating pipes join at the top of a boiler, for the flow pipe connection must not protrude beneath the uppermost plate.

Boot boilers, Figs. 243 and 244, provide a greater area of heating surface than the ordinary block type, and are often used for heating fairly large volumes of water. They provide

a large amount of indirect or flue surface when made as in Fig. 244, but it is necessary to be careful in considering it, and not to place too high a value upon it. Many kitchen ranges do not permit of the use of boot boilers, and, generally speaking, where large volumes of heated water are required, it is more economical and satisfactory to dispense with the range boiler and to substitute a good type of independent boiler. For large establishments where a great amount of cooking is done, range boilers are often a source of annoyance, as they greatly interfere with the heating of the ovens.

When a range boiler is a fair distance from front to back, and water containing temporary hardness is used, the return

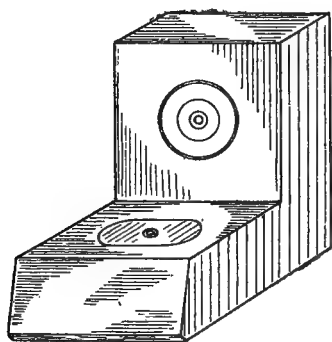


FIG. 243.—Boot boiler.

connection should be arranged so as to terminate near the front or toe of the boiler, as in Fig. 242. If this is done and the flow connection is located at the back, a better circulation will be maintained inside the boiler, and less saline matter will be deposited upon the boiler surfaces. Lime salts, as a rule, are not thrown out of solution to any great extent before the water approaches a temperature of about 180° F.,

but unless the heated particles of water are freely displaced from the front of a boiler, local currents may be set up, and when a big fire is burning, the water at the front may be considerably hotter than that at the back. If the circulation is restricted within a boiler, lime salts are freely deposited owing to the high temperatures recorded, whilst a free displacement of heated water tends to produce a more nearly uniform temperature within a boiler. It is specially desirable, where temporary hard water is used, that a range boiler takes a simple form, and that the heated water is not unnecessarily impeded in passing to the tank. The free circulation of water within a boiler is not a complete cure for the deposition of saline matter, but it is a simple means of reducing the trouble.

To remove scale from boilers, suitable hand holes should be provided which allow access to every part. The scale is usually thickest where the heat is greatest, and this accounts for the leakage of boilers through being burned. Apparatus may be arranged for preventing the deposition of lime salts and the formation of scale; this will be considered later.

The range boiler given in Fig. 245 differs from those previously given, in that the flame and heated products of combustion take a course over the front edge, down the centre flue, and up the back. This type of boiler, on account of the

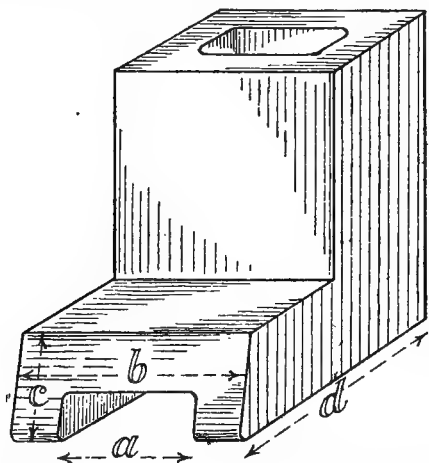


FIG. 244.—Boot boiler with arched and centre flue.

descending flue, will minimise the draught, and in consequence will consume less fuel in a given time, when compared with one where the flue passes directly beneath it and up the back. At the same time, the heating surface of a boiler like Fig. 245 will absorb less heat per unit area than one, say, like Fig. 242. The type shown in Fig. 245 is suitable for heating limited volumes of water, and its form of construction is advantageous where temporary hard water is used, as the salts are precipitated to the bottom, which is well below the level of the fire. The solid matter chiefly falls clear of the heated surfaces, and it can be removed in the form of sludge at the access

opening A. It is of course essential that saline matter is not allowed to accumulate and to reach the level of the fire, or the upper layers may be converted into a hard mass which

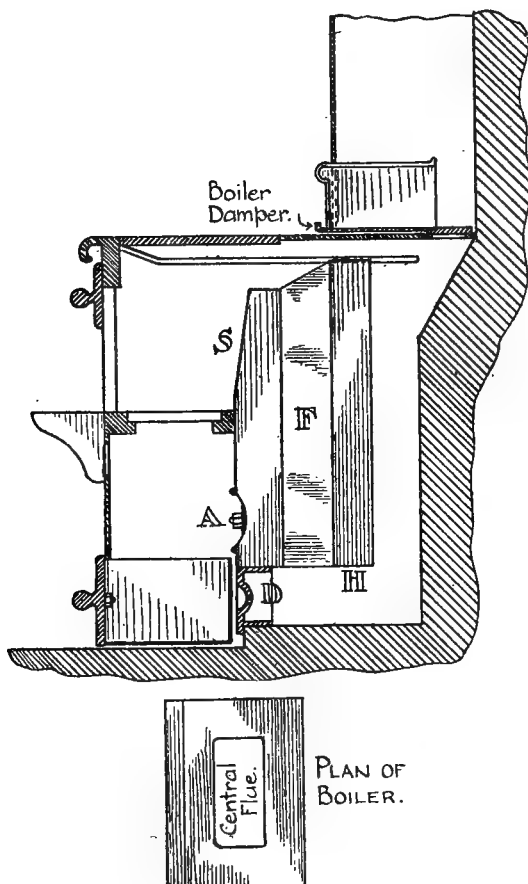


Fig. 245.—“Mermaid” boiler set in range.

can only be removed by the application of force. To enable the flues to be cleaned, a soot door D is provided in Fig. 245.

Independent Boilers take various forms, and are made in wrought iron, mild steel, cast iron, and copper. In Fig. 246, a dome-top type is shown, where the waterway sides are carried

beneath the fire bars. This form of boiler permits a great amount of heat to escape into the chimney, but its efficiency is increased if cross tubes are added. Cross tubes add to the initial cost of a boiler, but this is repaid by the amount of fuel

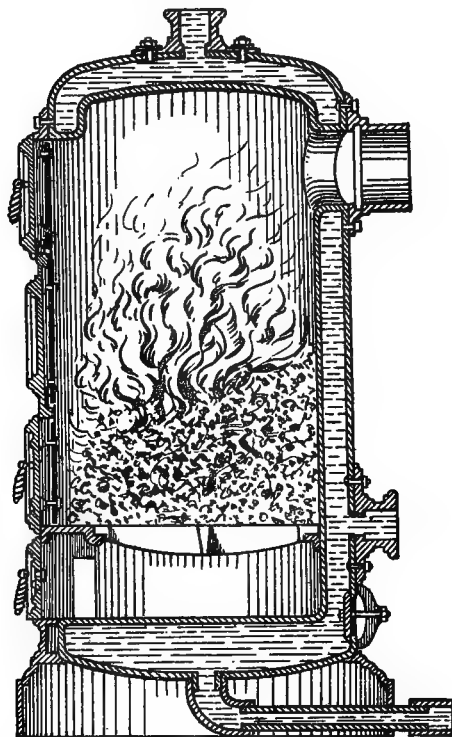


FIG. 246.—Independent boiler by Lumby Sons, Wood & Co. Ltd.

saved. Boilers are more fully considered in the next chapter, where other types are also given.

Duty of Range and Dome-Top Independent Boilers.—Some idea of the heating capacity of boilers is often required, especially when large volumes of water require to be heated in a limited time. The heat transmitted through a square foot of boiler surface varies considerably, and depends upon

the form it takes, and whether it is exposed to the direct heat of the fire or not. Surfaces in direct contact with fire absorb considerably more heat than indirect surfaces, as the former receive radiant heat from the fire, flame impact, and heated products of combustion. On the other hand, indirect surfaces (those which are not exposed to the fire) only receive heat from the products of combustion, and a certain amount from flame impact.

In order to simplify calculations in connection with range boilers, the vertical indirect surfaces which are only subjected to the ascending products of combustion will be omitted, as their precise value is difficult to ascertain. Under the best conditions the value of indirect surfaces is comparatively small, but an average approximate value for these surfaces will be included in the data given.

Formulæ for Range Boilers.—The following formula is applicable to range boilers for determining the approximate volume of water which can be raised in a given time from about 42° to 170° Fahr. when a good fire is burning:—

$$G = E \times q \times t. \quad (70)$$

Where G = gallons of water raised from 42° to 170° F.

„ E = effective heating surface of boiler in square inches.

„ q = a constant which varies with the type of boiler. (see Table XII).

„ t = time for heating water in hours.

TABLE XII.

VALUE OF q FOR DIFFERENT BOILERS

For types similar to Figs. 240 and 241 . . .	$q = \cdot 076$ or $\frac{19}{250}$
„ „ Fig. 243	$q = \cdot 083$ „ $\frac{83}{1000}$
„ „ „ 244	$q = \cdot 09$ „ $\frac{9}{100}$
„ „ „ 245	$q = \cdot 028$ „ $\frac{7}{250}$

The effective heating surface of boilers like Fig. 240 to Fig. 244 inclusive, is considered to be that at the front and

the bottom which is clear of brick or other settings. For a boiler similar to Fig. 245, the effective surface is taken as the front S, plus that of the centre flue F, plus the horizontal surface H, the lengths of the latter being considered equal to that of the centre flue. The arched flues of Figs. 241 and 244 may be ignored, and the dimensions taken as for plain boilers like Figs. 240 and 243.

A worked example or two will help to make the matter clear.

Example 40.—Assume the clear front of a boiler (Fig. 240) measures 12 inches by 6 inches and the bottom between the brick settings 8 inches by 12 inches. Find how many gallons such a boiler should be capable of heating in $1\frac{1}{2}$ hours.

By Formula 70, $G = E \times q \times t$.

Value of $E = (12 \times 6) + (8 \times 12)$ and in Table XII. $q = \cdot 076$.

Substituting values given,

$$G = [(12 \times 6) + (8 \times 12)] \times \cdot 076 \times 1\frac{1}{2},$$

$$G = \frac{168 \times \cdot 076 \times 3}{2};$$

$$\therefore G = 19\cdot 15, \text{ say } \underline{19 \text{ gallons.}}$$

Example 41.—If a boiler like Fig. 244 is used, and we desire its heating capacity per hour when, say, a measures 10 inches, b 15 inches, c 7 inches, and d 14 inches.

Formula 70 gives $G = E \times q \times t$.

$E = (b \times c) + (a \times d)$ and q from Table XII. $= \cdot 09$.

Substituting values given,

$$G = [(15 \times 7) + (10 \times 14)] \times \cdot 09 \times 1.$$

$$G = 245 \times \cdot 09;$$

$$\therefore G = 22\cdot 05, \text{ or say } \underline{22 \text{ gallons per hour.}}$$

Example 42.—Assume we require to ascertain the volume of water a boiler like Fig. 245 will heat per hour when its principal dimensions are as follows:—

Front S, 12 inches by 7 inches. Centre flue, 7 inches by 3 inches and 16 inches deep. Horizontal surface H, 4 inches wide.

Although the back is a little higher than the front, for

purposes of calculation this can be ignored. The surfaces which are taken into account are—front of boiler, centre flue, and the surface H.

By Formula 70, $G = E \times q \times t$.

To obtain the surface of the centre flue, first ascertain its perimeter and then multiply by its depth. Thus the perimeter of the flue given equals $2 \times (7 + 3) = 20$ inches.

Then $E = (12 \times 7) + (20 \times 16) + (7 \times 4)$. Value of q from Table XII. is given as .028,

and $G = [(12 \times 7) + (20 \times 16) + (7 \times 4)] \times 0.28 \times 1$,

$$G = 432 \times 0.028:$$

$\therefore G = 12.09$, or say 12 gallons per hour.

If we wish to ascertain the approximate time for heating a given volume of water we have by transposing Formula 70,

$$t = \frac{G}{E \times q} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (71)$$

Example 43.—How long will it take a boiler which is similar to Fig. 241 to raise 35 gallons of cold water to about 170° F.? Let $a=8$ inches, $b=14$ inches, $c=7$ inches, and $d=12$ inches.

By Formula 71, $t = \frac{G}{E \times q}$.

From Table XII, $q = .076$,

$$\text{and } t = \frac{G}{[(b \times c) + (a \times d)] \times 0.76}$$

Substituting values given, $t = \frac{35}{[(14 \times 7) + (8 \times 12)] \times .076}$;

$\therefore t = 2.37$, or 2 hours 22 minutes.

Formulæ for Dome-Top Independent Boilers.—The method of calculation which has been given for range boilers is not readily applicable to independent boilers. For the latter class, it is far better to determine their diameter when ascertaining their size than to compute the area of the heating surface. The efficiency of an independent boiler is controlled by the rate of combustion, by the arrangement and form of the heating surface, and by the ratio of the grate area to the heating

surface. When a given rate of firing is decided upon, and the kind of fuel to be used, the formula may take a simple form.

The following formulæ for dome-top boilers is applicable when the rate of firing is approximately 10 lb. of fuel per sq. foot of grate per hour, and when water is raised from 42° to about 180° F.:—

$$\text{For Coal Fuel, } G = \frac{d^2 \times t}{5} \quad . \quad . \quad . \quad . \quad . \quad (72)$$

$$t = \frac{5 \times G}{d^2} \quad . \quad . \quad . \quad . \quad . \quad (73)$$

$$d = \sqrt{\frac{5 \times G}{t}} \quad . \quad . \quad . \quad . \quad . \quad (74)$$

$$\text{For Gas Coke Fuel, } G = \frac{d^2 \times t \times 5}{32} \quad . \quad . \quad . \quad . \quad . \quad (75)$$

$$t = \frac{32 \times G}{5 \times d^2} \quad . \quad . \quad . \quad . \quad . \quad (76)$$

$$d = \sqrt{\frac{32 \times G}{5 \times t}} \quad . \quad . \quad . \quad . \quad . \quad (77)$$

Where G = gallons of water heated.

„ d = internal diameter of boiler.

„ t = approximate time in hours.

Example 44.—Determine the number of gallons of cold water which can be raised by an 11-inch internal diameter dome-top boiler in $2\frac{1}{2}$ hours when coal fuel is used.

$$\text{Using Formula 72, } G = \frac{d^2 \times t}{5}.$$

$$\text{Substituting values, } G = \frac{11^2 \times 2\frac{1}{2}}{5};$$

$$\therefore G = \underline{60\frac{1}{2} \text{ gallons.}}$$

Example 45.—What should be the internal diameter of a dome-top boiler to heat 75 gallons per hour when using coal fuel?

$$\text{By Formula 74, } d = \sqrt{\frac{5 \times G}{t}}.$$

$$\text{Substituting values, } d = \sqrt{\frac{5 \times 75}{1}};$$

$$\therefore d = 19.3, \text{ say } \underline{19 \text{ inches diameter.}}$$

Values computed by Formulæ 72 and 75 will generally be found lower than those given in a manufacturer's catalogue. Catalogue values are, as a rule, considerably overrated, and the basis upon which they are computed is often far from being satisfactory.

Sizes and Capacities of Hot-Water Tanks.—The capacity of a hot-water storage tank should be governed by the maximum demand for hot water in the minimum time, and by the power of the boiler or heater.

In a small private house the greatest volume demanded at any one time is usually for a bath, and a tank of 30 gallons capacity usually provides sufficient storage. Tanks of smaller capacity are often used in certain dwellings, chiefly for economical considerations when installing an apparatus, and not because a smaller tank possesses any other merit.

For large buildings, where hot water is freely used, the storage capacity requires to be liberal. Suppose, for example, that in half-an-hour 200 gallons of water at an approximate temperature of 104° are required. Taking the average temperature of the hot water in the tank at 166° , and the temperature of the cold water at 42° , equal volumes of cold and hot water would be necessary to produce the 200 gallons at the temperature desired. If a powerful boiler is used, say, one which is capable of heating 100 gallons of cold water to about 170° in one hour, then a storage capacity of 100 gallons would be ample. On the other hand, assuming that a similar volume of water is required, but only at long intervals, a less powerful boiler could be used and the storage capacity of the hot water tank increased by 30 to 50 per cent. The increased capacity is to compensate for the mixing of the cold with the hot water, when drawing off water for a rather prolonged period. The margin to be allowed, however, may also be governed by the dimensions of a tank. Cylindrical tanks when vertically placed, if of a comparatively small diameter, will do with a less margin than those of a larger diameter. Horizontally fixed cylindrical tanks require a larger marginal capacity than those which are vertically arranged.

The sizing of a tank according to the number of draw-off taps is no real guide, as the volume of water required, or used, is not directly proportional to the number of taps.

To arrive at the required capacity of a hot-water tank it is better to first ascertain the volume of hot water at a high temperature, which will produce along with cold water the volume required at any given lower temperature. To this a marginal capacity should be added of from 10 to 50 per cent. according to the power of the proposed boiler, the diameter of the tank, and the position of the latter when fixed.

Example 46.—Find the capacity of a cylinder which will hold sufficient hot water at an average temperature of 160° F. to produce 150 gallons of water at 120° F.

The temperature of the cold water is 44° .

First find the volume at 160° which will produce, along with cold water, 150 gallons at 120° .

Let x = volume of hot water at 160° , when $150 - x$ = volume of cold water at 44° .

If P = temperature of hottest water.

„ T = temperature of water desired.

„ t = temperature of cold water.

Then $x(P - T) = (150 - x)(T - t)$.

Substituting values given,

$$x(160 - 120) = (150 - x) \times (120 - 44).$$

$$\text{Simplifying } 40x = (150 - x) \times 76.$$

$$40x = 11400 - 76x.$$

$$116x = 11400.$$

$$\text{From which, } x = \frac{11400}{116} = 98 \frac{2}{13} \text{ gallons.}$$

Therefore the volume of hot water at 160° F., which is necessary to produce the volume required, may be taken as 98 gallons.

Assuming a few hours are required to heat this volume of water, the capacity of the cylinder may be increased by 40 per cent. when the final capacity = $98 + 39 = \underline{137 \text{ gallons.}}$

Sizes of Cylindrical Tanks.—From the following simple rules either the capacity in gallons or one dimension can be obtained when the remaining particulars are given :—

$$G = \frac{d^2 \times h}{353} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (78)$$

$$h = \frac{353 \times G}{d^2} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (79)$$

$$d = \sqrt{\frac{353 \times G}{h}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (80)$$

Where G = capacity in gallons.

„ h = height or length of tank in inches.

„ d = diameter in inches.

Example 47.—Find the volume of water a cylindrical tank will hold when its diameter is 2 ft. 9 in. and its height 4 ft. 6 in.

By Formula 78, $G = \frac{d^2 \times h}{353}$.

Substituting values, $G = \frac{33 \times 33 \times 54}{353}$;

$\therefore G = 166 \frac{208}{353}$, say 166½ gallons.

Example 48.—A cylindrical tank of 80 gallons capacity has a diameter of 20 inches, determine its height.

Using Formula 79, $h = \frac{353 \times G}{d^2}$.

Substituting values, $h = \frac{353 \times 80}{20 \times 20}$;

$\therefore h = 70 \frac{2}{5}$ inches, say 5 ft. 10½ in.

Example 49.—What diameter of cylinder would be required to hold 65 gallons when its height is 4 feet ?

By Formula 80, $d = \sqrt{\frac{353 \times G}{h}}$.

Substituting values, $d = \sqrt{\frac{353 \times 65}{48}}$;

$\therefore d = 21.8$ in., say 1 ft. 9¾ in.

Square and Rectangular Tanks.—The capacity of these tanks or any dimension can be obtained when the remaining values are given.

$$G = \frac{l \times b \times h}{277} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (81)$$

$$l = \frac{277 \times G}{b \times h} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (82)$$

$$b = \frac{277 \times G}{l \times h} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (83)$$

$$h = \frac{277 \times G}{l \times b} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (84)$$

Where G = contents in gallons.

„ l = length of tank in inches.

„ b = breadth in inches.

„ h = height or depth in inches.

Sizes of Pipes for Systems of Hot-Water Supply.—The sizes of circulating pipes between a boiler and a cylinder are usually determined by arbitrary rules; the chief thing is to provide a passage which will not unduly retard circulation. Where draw-off branches are taken from secondary circuits, the latter should be sized to properly supply the number of taps which are likely to be in use at the same time.

For a small system which is supplied with soft water $\frac{3}{4}$ -inch circulating pipes are usually satisfactory. If these pipes are long they should be increased in size. Larger circulation pipes are also desirable when they require to be trapped, in order to compensate for a slower rate of movement of the water.

In hard water districts where deposits occur in pipes and boilers, larger circulating pipes should be used than in soft water areas. An increase of one size is usually sufficient where the other conditions are similar. The return pipe, as a rule, is not materially affected by deposit, the salts which escape from the boiler being usually precipitated in the flow pipe.

For large systems where independent boilers are used, the minimum size of circulating pipes should be $1\frac{1}{2}$ inches diameter.

Generally speaking, feed pipes to cylinders should not be

less than one size larger than the principal draw-off pipes; a large feed pipe is specially necessary where there is only a short vertical distance between the top of the hot water tank and the bottom of the cold supply cistern.

For comparatively small systems the principal draw-off pipe from a cylinder does not require to exceed 1 inch diameter, but in the case of large installations where pipes are long, their sizes are better ascertained by the aid of hydraulic formula, when the special requirements of each system can be taken into account.

Steam Apparatus for Heating Water.—Steam, when available, as in many large buildings, is a very suitable and convenient agent for heating water, and it possesses the special advantage of being able to raise large volumes to a relatively high temperature in a limited time.

Properties of Steam.—To convert water at 212° F. into steam at the same temperature, requires 966 B.T.U. per pound of water. The *British thermal unit* is generally expressed by the abbreviation B.T.U., and represents the amount of heat necessary to raise one pound of water from 39° to 40° F. or, say, through one degree.

The heat which is necessary to convert water at any temperature into steam at the same temperature, is known as the *latent heat* of steam, and this value varies according to the pressure of the steam. For steam at atmospheric pressure (equivalent temperature 212° F.), its latent heat is 966, and for pressures less than that of the atmosphere, the value of the latent heat increases. On the other hand, when the pressure of steam exceeds that of the atmosphere, its latent heat is less than 966; in other words, less heat is necessary to change water from the liquid into the gaseous state.

As the heat which is stored in steam is given up upon its condensation, its value as a heating agent is apparent. For example, 1 lb. of steam at 15 lb. per sq. inch. (gauge pressure) when condensed and when the water of condensation is cooled to 150° F., gives up $939 + (250 - 150) = 1039$ B.T.U.

The value 939 is obtained from Table XIII. and is the latent heat of steam for the pressure given.

From the same Table, the value 250 will be found to

represent the temperature of the steam when subjected to a pressure of 15 lb. per sq. inch.

Boiling Point.—The boiling point of water is a variable quantity. At sea level water boils in an open vessel at 212° F., but if it is subjected to greater pressure by confining it in a closed vessel, the boiling point is raised. At high altitudes, water in an open vessel boils at less than 212°, and the same result is obtained when water is confined in a vessel, and when the air pressure in the vessel is reduced by an air pump or by other means.

TABLE XIII.
PROPERTIES OF STEAM.

Pressure in lb. per sq. inch.	Tempera- ture F.	Latent heat.	Pressure in lb. per sq. inch.	Tempera- ture F.	Latent heat.
Atmospheric	212	966	16	252	938
1	216	963	17	254	936
2	219	961	18	256	935
3	222	959	19	257	934
4	225	957	20	259	933
5	228	955	21	261	931
6	231	953	22	262	930
7	233	951	23	264	929
8	235	949	24	266	928
9	238	948	25	267	927
10	240	946	26	269	926
11	242	945	27	270	925
12	244	943	28	272	924
13	246	942	29	273	923
14	248	940	30	274	922
15	250	939	31	276	921

Heating Water by Steam.—There are two general methods of heating water by means of steam—(a) the direct method, where live steam is introduced into the water; and (b) the indirect method, where the steam and water are kept apart by arranging steam-heated surfaces which are surrounded with water.

The direct method is limited in its application, on account of the noise usually caused when steam and water come together, and the increase in volume of the water due to

condensation of steam. This mode of heating water, however, is often suitable for industrial purposes, and for heating water in swimming ponds as well as for other special uses.

For general work indirect steam heating is necessary, but less heat is abstracted from a given weight of steam than with the direct method. One of the simplest forms of indirect steam heaters is shown in Fig. 247. A copper coil in the cylinder takes the place of a boiler, steam being admitted at the upper part, whilst the water of condensation drains to a steam trap T, which is located in any convenient place. The feed and draw-

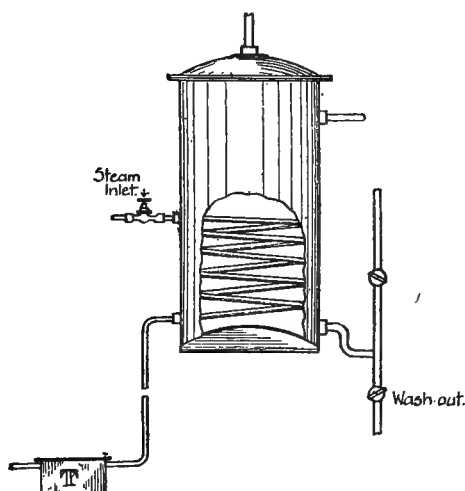


FIG. 247.—Steam heater. (Union connections omitted.)

off pipes in connection with the cylindrical tank are arranged as in systems where boilers are used.

If the water of condensation could be arranged to gravitate to the boiler, a steam trap may not be necessary, but where steam is taken from a high-pressure boiler, and its pressure is reduced before being admitted to a heater, a steam trap is imperative unless some other contrivance is introduced.

The tubes of steam heaters or calorifiers, as they are frequently termed, take different forms and they are arranged in a variety of ways. So far as the amount of heat which is abstracted from a given weight of steam is concerned, one form

of heater is as effective as another. It is, however, customary when comparing steam heaters to speak of one form as being more efficient than another type, and the term should not be taken to indicate that one form of heater uses less steam than another to do a specific amount of work, but only, that a particular arrangement of the tubes will condense more steam in unit time per unit area than that of a different design. In other words, one form of heater will do work quicker than

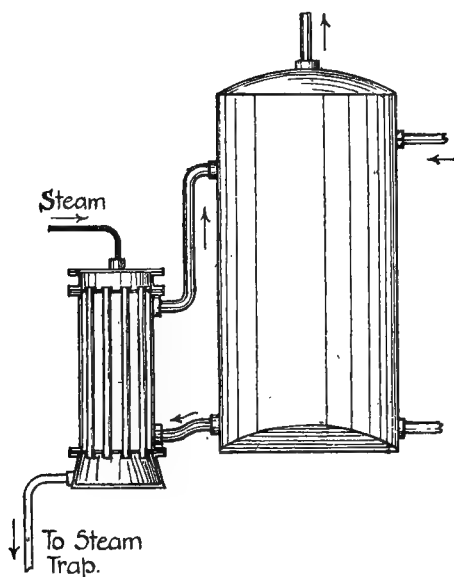


FIG. 248.—Steam heater or calorifier (Union connections omitted.)

another, but the consumption of steam is practically the same with different types for the same work done.

Generally speaking, straight plain vertical tubes transmit heat more slowly than other forms per unit area, and the reason for this is, that instead of the water of condensation spreading evenly over the whole surface of the tubes, it trickles down them in streams, and leaves a large area not wetted. Coils are therefore largely adopted for heaters, as the retardation introduced by changes of direction permits of a greater tube

surface being wetted, and the rate of the heat transmission is consequently increased.

Instead of placing a coil inside a tank, as in Fig. 247, the heater is often fixed as an independent unit, as in Fig. 248. This arrangement is sometimes preferable, for when a heater requires to be repaired it can be readily detached from the tank. In Fig. 247 the tank is shown with a removable top, in order to render the coil accessible. The heater in Fig. 248

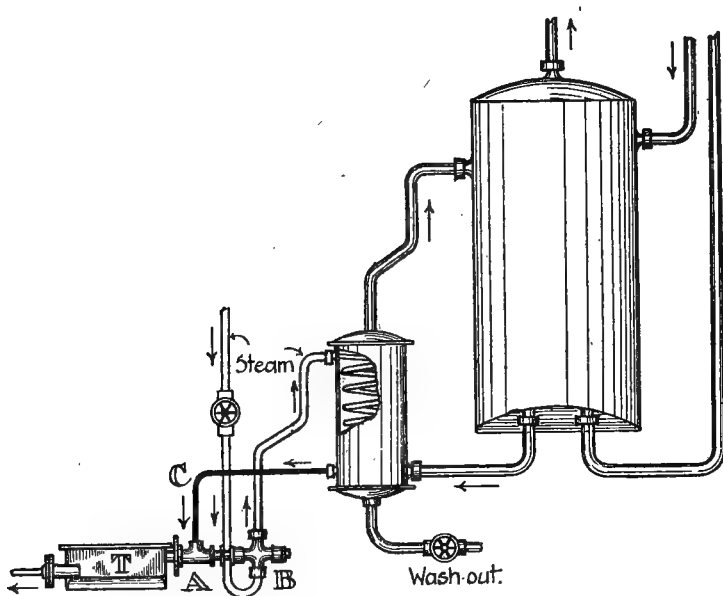


FIG. 249.—Steam heater with automatic device for controlling steam supply.

consists of a number of tubes which communicate with steam spaces at the ends. Flow and return pipes are arranged in the ordinary manner. A safety valve may be necessary at the top of the heater, but this principally depends upon the strength of the casing and the pressure of the steam.

When coils are used for heaters, their length, as a rule, should not greatly exceed 150 diameters, otherwise their lower parts may be useless for transmitting heat. Thus for a coil of 1-inch copper tube its maximum length should be about

12 feet. Where a greater length of tube is necessary to transmit the requisite quantity of heat, two or more coils should be formed.

To obviate overheating, and to prevent waste of steam, it is essential that a heater be provided with some device for automatically controlling the steam supply. There are various means of accomplishing this end, one method being shown in Fig. 249, where the steam valve is operated by a steam trap T. To the inlet A of the trap a spindle is connected, the other end of the spindle being joined with the steam valve B. The trap is of the expanding and contracting type, and is more clearly shown in Fig. 251.

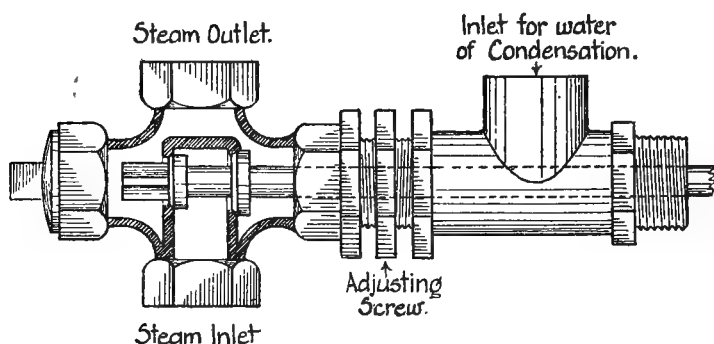


FIG. 250. — Automatic steam valve.

The automatic valve in Fig. 249 is brought into action as follows: So long as there remains a certain difference in temperature between the steam and the water to be heated, the steam is condensed, and the water of condensation is discharged through the trap. When the temperature of the water in the heater is raised, the valve of the steam trap is gradually closed, and in turn operates to close the steam valve B. In this manner the supply of steam is controlled to suit the rate of condensation, and when the water has reached the temperature for which the appliance has been adjusted, the supply of steam is cut off.

Figs. 250 and 251 give sections of the automatic steam valve and trap, which are shown in position in Fig. 249.

In the trap Fig. 251 a copper tube is arranged in the form of a bow, and when it is subjected to increased temperature the rate of expansion tends to straighten the tube and to close the inlet valve. Upon the tube cooling, contraction takes place, and the bow regains its normal position when the valve is again opened. In order to make this form of trap sensitive to changes of temperature, the copper tube is sometimes charged with a volatile liquid.

Steam Traps take many forms, and their use becomes necessary in steam heating work, where the water of condensation cannot be returned directly to the boiler. The primary purpose of a steam trap is to deal with the water

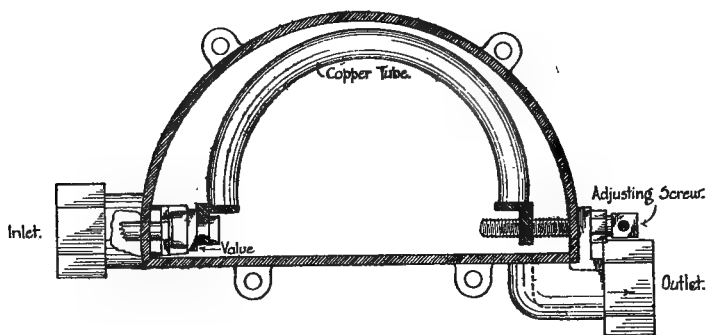


FIG. 251.—Section of steam trap which is used in conjunction with valve shown in Fig. 250.

of condensation, and to avoid unnecessary waste of steam. As a rule the most effective form of steam trap is the box type, and when circumstances will permit of its use it should be adopted. The initial cost of the box type may be higher than other forms, but it is by far the cheapest in the end.

Fig. 252 gives a very good form of box trap, by Lancaster and Tonge, where the opening and closing of valve S is accomplished by a quick screw motion when the float E falls and rises. To the top of the float an adjustable air-valve N is attached, to which is joined a tube, which terminates near the bottom of the float. The small orifice in the upper part of the tube is to admit of the escape of air, which would otherwise be confined in the float and interfere with the working of the

trap. To start the trap, water is poured into it after the cover is removed, until the overflow or outlet is reached. As water enters the float through the aperture F, it begins to sink and to open the valve, when the water of condensation can be discharged. So long as water only flows into the trap, the ball

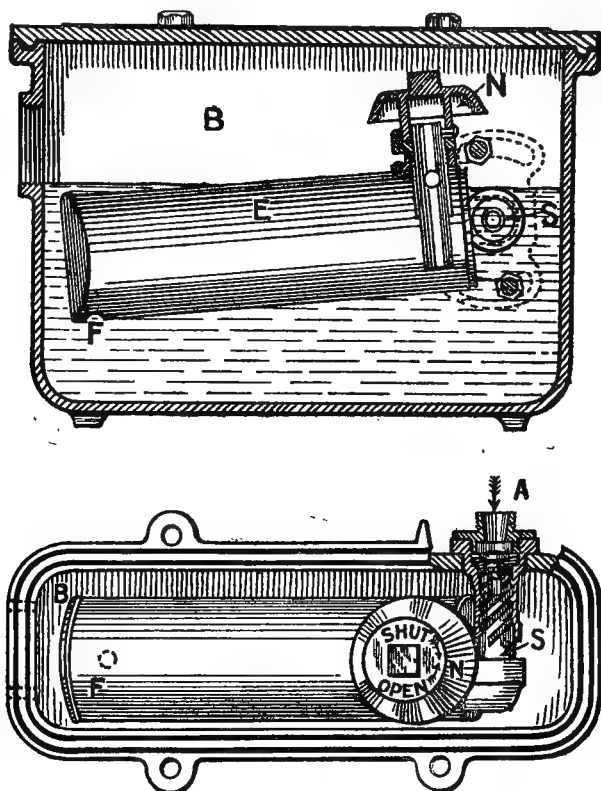


FIG. 252.—Lancaster and Tonge's steam trap.

will remain submerged, but when steam reaches and enters the float, the water is displaced at N and through the small aperture F in the float, until the latter is rendered buoyant and the valve S is closed. After a short time the steam in the float is condensed, and water again enters until its buoyancy is destroyed. If, in the interval, water has accumulated at

the valve, it is immediately discharged, but when steam appears the float is again raised and the valve S closed.

Heat transmitted by Steam Heated Coils when surrounded with Water.—The amount of heat transmitted through tubes is governed by the temperature or pressure of the steam, by the initial temperature of the water to be heated, by the form the tube takes, and whether the whole of the heating surface is effective or not.

As regards the pressure of steam, the higher it is the greater is the difference between the temperature of the heating medium and that of the water to be heated, and consequently the quicker the rate of heat transmission. When water is being heated in a calorifier with steam, the rise of temperature will not be at a uniform rate, but quickest at the commencement when the water is cold.

If, for example, we assume that a volume of water requires to be raised from 44° to 180° with steam at 15 lb. pressure per sq. inch (equivalent temperature 250° F.), the difference in temperature between the steam and the cold water is $250 - 44 = 206^{\circ}$, and the difference between the steam and the hottest water $250 - 180 = 70^{\circ}$. As the maximum difference of temperature coincides with the maximum rate of heat transmission when other conditions are equal, it is obvious that as the temperature of the water is raised the rate of heat transmission will accordingly be reduced, and for the case given will be at a minimum when the temperature of the water is 180° .

For purposes of calculation it is usual to take the average difference of temperature in order to simplify matters, and although this may not give results which are strictly correct they are usually sufficiently accurate for ordinary work. Thus where the temperature of the steam is 250° , and that of the cold and hottest water 44° and 180° F. respectively, the average difference of temperature for the steam and water will be

$$250 - \frac{180 + 44}{2} = 138^{\circ}.$$

The following Table gives the approximate number of heat units which are transmitted per minute per square foot of surface per degree difference of average temperature for short coils.

TABLE XIV.

Steam pressure per square inch.	Heat transmitted in B.T.U. per minute per sq. foot of surface per degree difference of temperature.
5 lb. (temp. 228°)	4.5
15 „ (temp. 250°)	6
30 „ (temp. 274°)	8

The above values are for an initial temperature of 44° and a maximum temperature of about 180°. By the aid of the following formulæ calculations in connection with steam heaters may be made:—

$$l = \frac{38 \times G \times (T - t)}{\left(P - \frac{T + t}{2}\right) \times U \times d \times m} \quad . \quad . \quad . \quad (85)$$

$$G = \frac{\left(P - \frac{T + t}{2}\right) \times U \times d \times l \times m}{38 \times (T - t)} \quad . \quad . \quad . \quad (86)$$

$$m = \frac{38 \times G \times (T - t)}{\left(P - \frac{T + t}{2}\right) \times U \times d \times l} \quad . \quad . \quad . \quad (87)$$

Where G = gallons of water heated.

„ T = temperature of hottest water.

„ t = temperature of cold water.

„ P = temperature of steam.

„ U = B.T.U. transmitted per minute from Table XIV.

„ d = external diameter of tube in inches.

„ l = length of tube in feet.

„ m = time in minutes heating water.

Example 50.—Determine the length of coil when formed of 1-inch copper tube which will raise 130 gallons of water in 20 minutes from 42° to 180° F. Assume the steam is supplied at 15 lb. per sq. inch.

$$\text{By Formula 85, } l = \frac{38 \times G \times (T - t)}{\left(P - \frac{T + t}{2}\right) \times U \times d \times m}$$

In Table XIV. the values of P and U are given as 250° and 6 respectively.

$$\text{Substituting values given, } l = \frac{38 \times 130 \times (180 - 42)}{\left(250 - \frac{180 + 42}{2}\right) \times 6 \times 1 \times 20}$$

$$l = \frac{38 \times 130 \times 138}{139 \times 6 \times 20};$$

$$\therefore l = 40\frac{1}{3}\frac{2}{3} \text{ ft., say } 40 \text{ ft. } 10 \text{ in.}$$

Example 51.—If a steam heater contains a coil of 1-inch copper tube which is 10 feet long, how many gallons of water would it raise per hour from 44° to 180° F. when supplied with steam at 30 lb. gauge pressure?

$$\text{Using Formula 86, } G = \frac{\left(P - \frac{T+t}{2}\right) \times U \times m \times d \times l}{38 \times (T-t)}.$$

Values of P and U from Table XIV. are 274° and 8 respectively.

Substituting values given,

$$G = \frac{\left(274 - \frac{180 + 44}{2}\right) \times 8 \times 60 \times 1 \times 10}{38 \times (180 - 44)},$$

$$G = \frac{162 \times 8 \times 60 \times 10}{38 \times 136};$$

$$\therefore G = 150\frac{1}{3}\frac{5}{8}, \text{ or say } 150 \text{ gallons.}$$

Example 52.—Ascertain how many minutes it will take a calorifier to raise 350 gallons from 42° to 178° F. when the total length of the 1-inch copper coils is 50 feet and when the steam pressure is 30 lb. per sq. inch.

$$\text{By Formula 87, } m = \frac{38 \times G \times (T-t)}{\left(P - \frac{T+t}{2}\right) \times U \times d \times l}$$

Substituting values given,

$$m = \frac{38 \times 350 \times (178 - 42)}{\left(274 - \frac{178 + 42}{2}\right) \times 8 \times 1 \times 50}$$

$$m = \frac{38 \times 350 \times 136}{164 \times 8 \times 50};$$

$$\therefore m = 27\frac{47}{82}, \text{ or say } 27\frac{1}{2} \text{ minutes.}$$

As the arrangement of heating surface in calorifiers is a very important factor as regards the rate of heat transmission, it is necessary that experiments be carried out, in order to ascertain the actual value of U , for any special form of heater.

Indirect Systems of Hot Water Heating.—The systems to be dealt with in this case are confined to those where hot water is the indirect heating medium, and where range or independent boilers form the direct or primary heaters. Indirect heaters of this type are only suitable for waters which cause incrustation difficulties, as they are much more expensive to instal and much slower in action than direct heaters.

It has been previously stated that the deposition of lime salts from temporary hard water chiefly takes place when water has its temperature raised to over 180° F. An indirect system is therefore designed that the water which is withdrawn from it will not readily have its temperature raised to 180° F. The amount of solid matter which is precipitated from water will depend upon the nature and amount of hardness the water contains, upon the temperature to which the water is raised, and upon the volume used.

For example, supposing that 500 gallons of hot water are required in an establishment per day, that the water contains 15 degrees of hardness, and that when raised to 212° F. 10 degrees of hardness are eliminated. Of course it is not likely that the whole of this volume under usual conditions would be raised to anything like 212° , and for our case we will assume that only 20 per cent. or 100 gallons reaches that temperature. Upon this basis the amount of solid matter precipitated in a period of three months (91 days) would be $100 \times 10 \times 91 = 91,000$ grains, or 13 lb. It is therefore obvious that, unless some measures are adopted to prevent the deposition of lime salts, a boiler may rapidly be destroyed.

Fig. 253 gives an indirect system for heating water, where

B represents an independent boiler, H the indirect heater, C the outer cylindrical tank from which water is withdrawn at the various taps. A small tank T supplies the boiler and

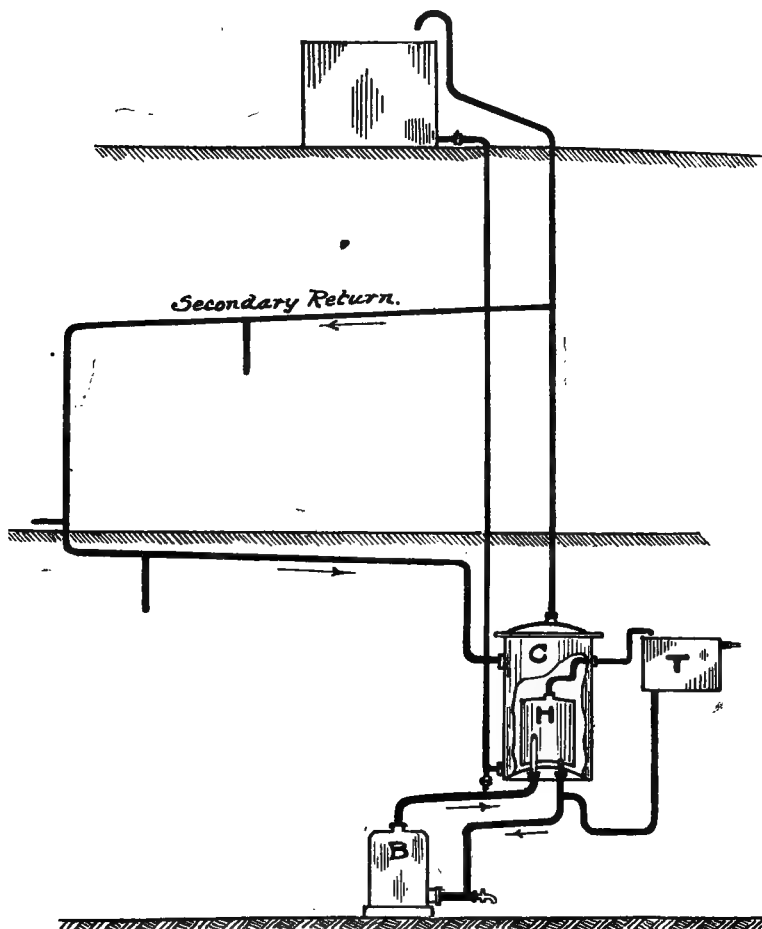


FIG. 253.—Indirect heating system.

indirect heater with water. It will be observed that no water is withdrawn from the indirect heater, the same water being heated over and over again, and any loss is made good by

means of the small supply tank T. From the top of H an air-pipe is taken and terminates as shown, the small tank serving the purpose of an expansion as well as a supply tank. It is only necessary for the bottom of tank T to be just above, or on the same level as, the top of the indirect heater, for the less the head the smaller will be the maximum temperature to which water in the indirect heater can be raised.

In an open vessel water at sea level boils at 212° , but when a boiler or indirect heater is subjected to pressure the boiling point of water is increased. For example, suppose the vertical distance between the top of the indirect heater and the level of the water in the supply tank T, Fig. 253, is 8 inches, the boiling point would be approximately 213° . Should, however, the vertical distance between the supply tank and the boiler in an ordinary system be 35 feet, the boiling point at the lowest level would be raised to 250° . The further application of heat when the boiling point is reached does not increase the temperature of the water, but the latter is converted into steam at the same temperature.

It will thus be clear that, in a system like Fig. 253, the water in the indirect heater H can never get much hotter than 212° F.; moreover, as a difference of temperature must exist between the water in the indirect heater and that in the cylinder C before heat can be transmitted from the former to the latter, the maximum temperature in C will be less than 212° . As a rule the water in the outer cylinder will not greatly exceed 170° F.

By arranging the indirect heater as in Fig. 253, the flow and return connections can be conveniently made at the bottom of the cylinder. Where an independent boiler is used, one with a water passage beneath the fire bars is preferable, although little solid matter can be deposited, owing to the water being seldom renewed. The cold supply pipe from an overhead cistern, and the secondary returns, are arranged as in other systems.

The following table gives the temperature at which water boils when subjected to varying heads :—

TABLE XV.

Head of water.	Boiling temperature F.	Head of water.	Boiling temperature F.	Head of water.	Boiling temperature F.
0 ft. 8 in.	213	23 ft. 9 in.	240	46 ft. 10 in.	259
3 " 0 "	216	26 " 1 "	242	49 " 2 "	261
5 " 3 "	219	28 " 5 "	244	51 " 6 "	262
7 " 7 "	222	30 " 9 "	246	53 " 10 "	264
9 " 11 "	225	33 " 0 "	248	56 " 1 "	266
12 " 3 "	228	35 " 4 "	250	58 " 5 "	267
14 " 6 "	230	37 " 8 "	252	60 " 9 "	269
16 " 10 "	233	39 " 11 "	254	80 " 10 "	281
19 " 2 "	235	42 " 3 "	256	103 " 11 "	292
21 " 6 "	238	44 " 7 "	257	128 " 2 "	303

It is important that an indirect heater contains sufficient surface to dissipate the heat as quickly as received. If we

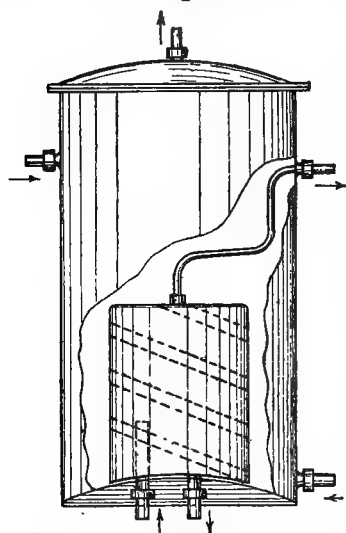


FIG. 254.—Indirect heater.

assume when heating the water in a system that the area of the indirect heater is equal to the effective boiler surface, the former would readily impart to the cold water surrounding it all the heat the boiler could transmit. When, however, the temperature of the water in the indirect heater and that surrounding it do not differ much, the area of the indirect heater on the above basis may be too small, and unless the fire were checked the water may soon boil in the heater. As a rule the surface of an indirect heater may be from 3 to $4\frac{1}{2}$ times the area of the

effective boiler surface, the smaller value being used for boilers with controlled draught, and the larger value for boilers without automatic control.

To increase the surface of an indirect heater without

increasing its water capacity, cross tubes may be inserted as in Fig. 254. This would increase the initial cost of the indirect heater, but a saving would be effected on the size of the external cylindrical tank.

Fig. 255 gives a section of the "Sylphon Automatic Temperature Regulator" for hot-water boilers, by the National

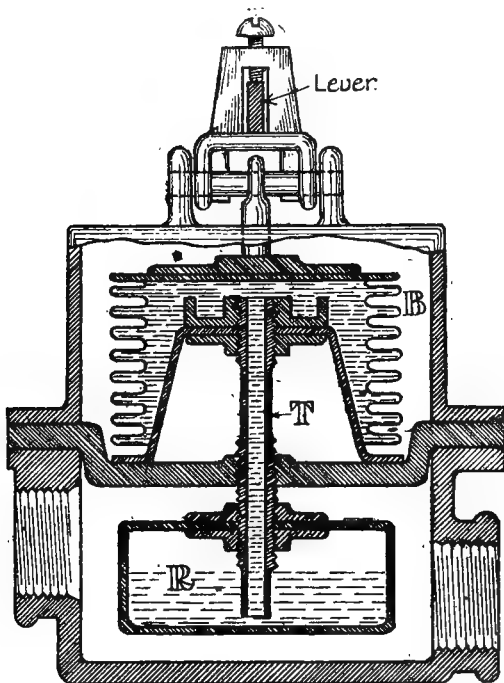


FIG. 255.—"Sylphon" automatic temperature regulator by National Radiator Co. Ltd.

Radiator Company Ltd., and Fig. 256 shows the appliance in position. The regulator consists principally of a metal bellows B, and a lower sealed vessel R which is joined to the bellows by means of a central tube T. The bellows is fully charged, whilst the vessel beneath is partially filled with a fluid which is volatilised at a comparatively low temperature, and this supplies the energy for operating the appliance. When a certain temperature is reached the confined liquid is converted into the

gaseous state, when the internal pressure expands the bellows B, and imparts motion to the weighted lever on the top of the appliance. To one end of the lever arm a chain may be joined as in Fig. 256, when upon the expansion of the bellows the draught damper is closed whilst the check damper in the flue is opened. Under these conditions the draught is checked, for the air supply to the fire is diminished, and simultaneously with this, air is admitted into the flue by the opening of the

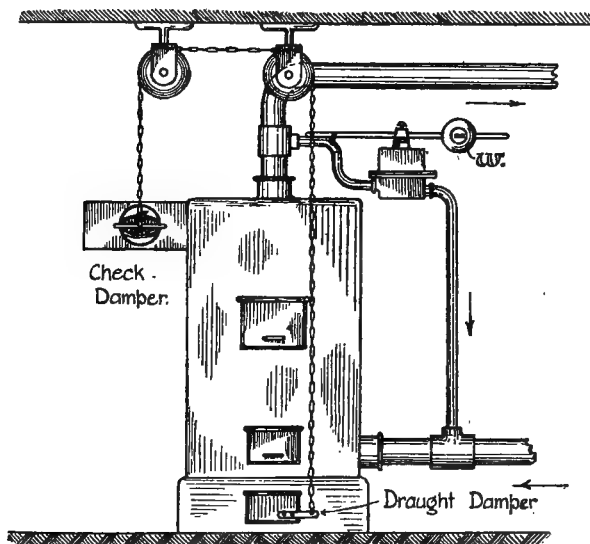


FIG. 256.¹—Automatic regulator attached to boiler.

check damper. When the vapour reassumes its liquid state, owing to a cooling action having taken place, the bellows contracts and the position of the dampers is reversed. In this manner the rate of combustion is automatically adjusted to suit the demand made upon the system. By shifting the weight on the lever the temperature at which the regulator can be brought into action is said to vary from 90° to 190° F.

Collapse of Copper Cylinders.—Hot-water cylinders collapse when the metal of which they are made is not sufficiently rigid to withstand a reduced internal pressure, and although cylinders

¹ The automatic regulator is more frequently fixed directly on the boiler than in a branch circuit as shown.

collapse under different conditions, the real cause is the same in each particular case.

A very common cause of cylinder collapse is due to the air or expansion pipe being trapped, so that the free escape of air from the system is prevented. Fig. 257 will aid in making

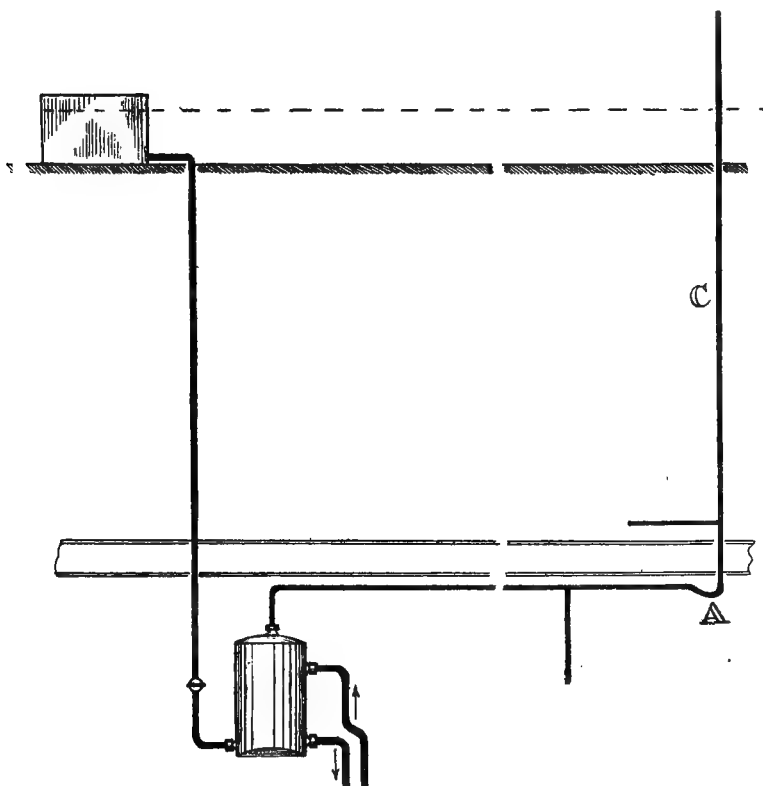


FIG. 257.—Illustration showing how a cylinder may be collapsed.

this clear. Supposing an expansion or air-pipe is fixed immediately beneath a ceiling, as in the figure shown, it is quite possible for this pipe not to rise for the whole of its length. Should the pipe be of lead and be supported with hooks or clips, after a time it will sag between the points of support, or, when the pipe passes through a ceiling to a floor

above, the vertical part may slip down a little, and produce a sag as at A, Fig. 257. In either case the air given out by heating the water would lodge in the horizontal air-pipe. Should water be withdrawn, the accumulated air would be relieved, and pass along with the water, or escape at the air-pipe. If, however, the water in the cylinder is heated, and none is withdrawn, air would accumulate in the horizontal pipe. Should overheating take place, steam also gathers at the highest point, when the water is gradually forced from the cylinder back through the feed-pipe to make room for the steam. The reason why the steam and air cannot escape through the air-pipe is rendered clear when one considers that before these can be dislodged the water in front of them must be first displaced through the dip at A, Fig. 257. As the displacement of the water round the dip must raise the column in C, the pressure here would exceed that due to the head of water in the supply cistern. The least line of resistance under these conditions is offered by the supply pipe, and through that pipe, either part or nearly the whole contents of the cylinder may be dislodged, provided the generation of steam continues. So long as the steam pressure is maintained inside the tank nothing serious happens, but when the system begins to cool, condensation of the steam takes place, when a partial vacuum is produced. If the cylinder at this period is unable to resist the reduced pressure, the sides give way and a collapse is the result.

Another way in which a cylinder may collapse is when the feed and expansion pipes are blocked with ice, and an attempt is made to withdraw the water by opening the sludge or emptying cock. In a similar manner the upper cylinders in connection with tenement buildings, when treated as in Fig. 237, occasionally collapse. For example, if the water in the supply pipe to the cylinders is frozen near the cistern, and the upper part of the air-pipes are also blocked with ice, the opening of a draw-off tap at a low level would cause water to be removed from the upper cylinders, when the latter would collapse.

The most common cause of cylinder collapse is probably due to the expansion pipes getting locked with air.

Prevention of Collapse.—When the cause is known it is a simple matter to guard against a cylinder being collapsed. In the first place, a collapse can only be brought about when the external pressure exceeds that inside, and to obviate this the air or expansion pipes should be arranged and sized, that air can freely enter or escape from them. If pipes are located in exposed positions, they should be protected from the frost by well covering them with hair felt or other suitable material.

A Float Valve may be fixed at the top of a cylinder tank to prevent collapse, but as a rule this appliance is not necessary. These valves are arranged to open and to admit air as soon as the water level inside the tanks begins to fall, but they close as the water level is raised.

Vacuum valves are also used for the same purpose ; these are intended to open and to admit air should a partial vacuum be formed. The value of the latter class of valve is doubtful, for should they stick a little at a critical time a sufficiently reduced pressure may occur to bring about the collapse of a tank.

Noises in Boilers.—These are generally produced by—

- (a) Boilers in which air is confined.
- (b) Overheating of the water.
- (c) Partially choked circulating pipes.

In the first case, when air is trapped inside a boiler, a portion of it escapes when expanded, and produces a rumbling sound as it rises through the water to the outlet. The air of course is replenished through the renewal of the water.

In the second case, the noises produced are similar to the above, only that they may be more pronounced. When water is overheated, steam is produced as it rises to a higher level owing to its being subjected to a lower pressure. Overheating is chiefly the result of retarded circulations, or it may be caused by a too powerful boiler being used.

Partially choked circulating pipes often produce thumping sounds. It is seldom that a flow-pipe is totally blocked with lime deposits, although its bore may be reduced in some cases

to one-third its original size. The return pipe, as a rule, is not affected to any great extent with deposited matter. When a flow-pipe is totally or partially choked, very violent thuds may be produced, although an explosion would not occur so long as the boiler return remained clear. The boiler, of course, is subject to damage by being burned, and by being subjected to considerable strain.

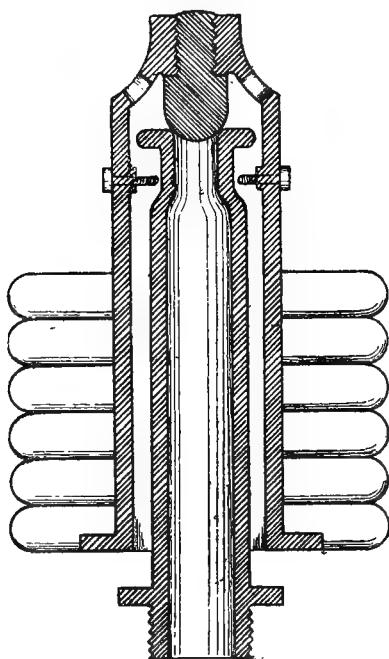


FIG. 258.—Dead-weight safety valve.

Boiler Explosions.—

The most common cause of boiler explosion in connection with hot-water apparatus is due to pipes being choked with ice. Stop-cocks in circulating pipes are occasionally responsible for it where safety valves have not been provided. It is also possible, under favourable conditions, for an explosion to be caused by cold water gaining admission to a boiler when the latter has been deprived of water and when heated to redness. From experiments it has been found that so long as the pressure due to the sudden generation of steam can be relieved through the supply pipe (assuming all

other passages to be choked), an explosion will not take place. On the other hand, when the feed-pipe will not afford the necessary relief, owing to a screw-down stop tap acting as a non-return valve, the pressure due to the sudden generation of steam may cause the boiler to explode. The latter cause may be rare, but the possibility exists under the conditions named.

Safety Valves.—The question is often asked, should boilers in connection with hot water supplies be provided with safety

valves? No doubt they should be used where they are sometimes absent, but in many cases safety valves can be safely dispensed with. For example, when either wrought iron or copper boilers are used, and where no trouble is caused by the deposition of lime salts, and provided boilers and pipes are arranged on inside walls, well away from the influence of frost, then under these conditions safety valves are not of much importance. Where, however, pipes are not properly protected, or where there is danger of their getting blocked with ice, or choked in any other manner, safety valves should be used. When cast-iron boilers are adopted, safety valves should be used, and in this case their use should be made compulsory, for the explosion of a cast-iron boiler may be attended with disastrous consequences.

With regard to the position in which safety valves should be placed, no hard-and-fast line need be laid down, and each case should be treated upon its own merits. Where stoppages are not likely to occur in the primary circulating pipes, a safety valve may be fixed in any convenient place, either at the boiler or on one of the circulating pipes.

From a general standpoint a safety valve should be fixed directly on a boiler. This, however, is not always practicable, especially with range boilers, and in many cases it is either necessary to fix a separate pipe to the boiler for receiving the safety valve, or to fix the latter to one of the circulating pipes. Where trouble is caused by saline matter being deposited from water, a safety valve may, with advantage, be joined with a return circulating pipe, and as near to the boiler as possible. The latter position, under the conditions given, is the least likely to be affected by deposit, and if fixed directly to the top of the boiler there is the possibility of its being rendered useless. In the case of boot boilers, where soft water is used, safety valves may be fixed directly to the boiler, but when they are fixed in flues they require to be protected with a suitable form of loose cover.

A safety valve, as a rule, should not be fixed on the top of a range, for in such a place it is liable to be knocked, and caused to leak.

Safety valves for boilers take various forms. The dead-

weight type, Fig. 258, is commonly employed, and it is simply constructed, the valve orifice being covered with a metal plug which is screwed to the top of the outer casing; over the latter loose weights are placed, the load being governed by the pressure at which the valve is to come into action.

Another type of dead-weight valve (Jeffrey's patent) is shown in Fig. 259. This form of construction is intended to make the valve less liable to leakage if it should be given an accidental knock, or be jarred in any way. Instead of

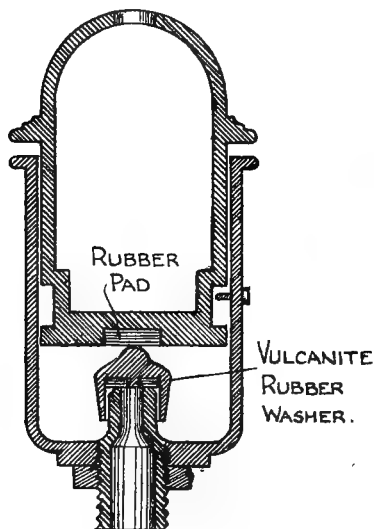


FIG. 259.—Jeffrey's dead-weight safety valve.

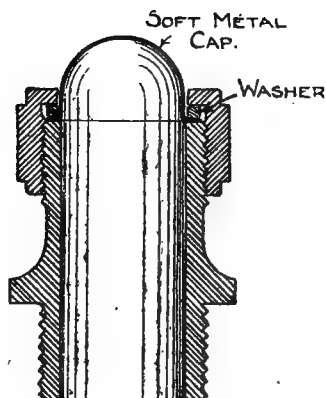


FIG. 260.—Croydon relief valve.

using a hard metal to metal facing, as in Fig. 258, the valve seating is covered by a vulcanite rubber washer in a cast-iron cap, the latter in turn being pressed upon by a rubber pad which is inserted in the upper casing of the valve. It will be observed that the upper part of the valve is hollow, and by introducing lead or shot the safety valve may be loaded to any reasonable extent. When fixed, this valve should not be subjected to the heated products of combustion, otherwise the rubber pad may be soon destroyed and the valve caused to leak.

Fig. 260 gives a different type of valve to either of the foregoing. In this case, relief is brought about when the soft metal cap gives way. Another valve which is similar in principle has a thin mica disc in lieu of the metal cap. Such

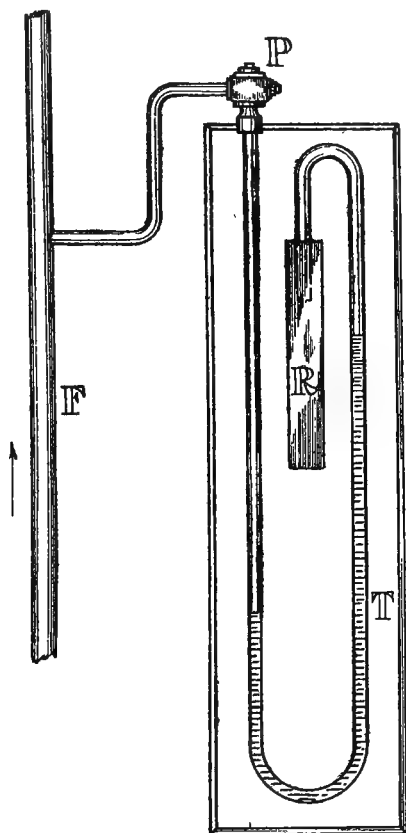


FIG. 261.—Macintosh's mercury gauge and relief.

valves, however, cannot be adjusted with the same precision as the dead-weight type.

Spring safety valves are also largely used, the spring being either in a state of tension or of compression. Generally speaking, they are not so suitable for kitchen boilers as the dead-weight type.

An arrangement which can be used in many cases, and which is less likely to get out of order than any form of valve, is the mercury gauge and relief (Macintosh's patent), Fig. 261. The glass tube T contains mercury, the pressure of which must exceed the normal pressure of water in the apparatus. This arrangement is intended to be joined with a flow-pipe F, and should the mercury be subjected to increased pressure, the necessary relief is afforded by the mercury being dislodged from the tube into the receiver R. To charge the tube with mercury the plug P is removed at the top of the gauge.

CHAPTER XIV

LOW PRESSURE HOT-WATER HEATING APPARATUS

IN the British Isles, where provision is made for warming buildings other than that by open fires, low pressure hot-water apparatus is frequently installed. For general residence and horticultural work this mode of heating has much in its favour, as the temperature of the heating surfaces can be regulated to suit different requirements, and a mild and humid atmosphere can be maintained.

For warming large buildings, low pressure steam may be a more suitable heating medium, and in the case of factories and workshops where steam is often available it becomes unnecessary to provide a different heating agent. Either live or exhaust steam is suitable for warming purposes.

In large rooms, where a big number of people congregate, a heating system should be installed which can be readily cooled down should the place get overheated.

When the amount of heat that is stored in a volume of hot water is compared with the amount of heat contained in an equal volume of steam, it will be found that the latter contains less than one-hundredth the amount of the former, when the temperatures of the water and steam are 180° and 228° F. respectively. Thus it is evident that water is comparatively slow in giving up its heat, and therefore not so suited as steam where quick fluctuations of temperature are desired.

Systems of Piping.—There are three general ways for arranging the piping in connection with low pressure hot-water apparatus—

- (a) One pipe up-feed system.
- (b) Two pipe up-feed system.
- (c) Overhead, or drop system.

In the *one pipe* system the main circuit is everywhere of the same diameter, whilst in a *two pipe* system the mains are sized according to the amount of heating surface to be served. The *overhead* or *drop* system consists mainly of vertical returns, and represents a modification and combination of the *one* and *two pipe* systems.

Fig. 262 shows a *one pipe* system when arranged for a single storey building, and it will be observed that the flow and return connections to and from each radiator join the same

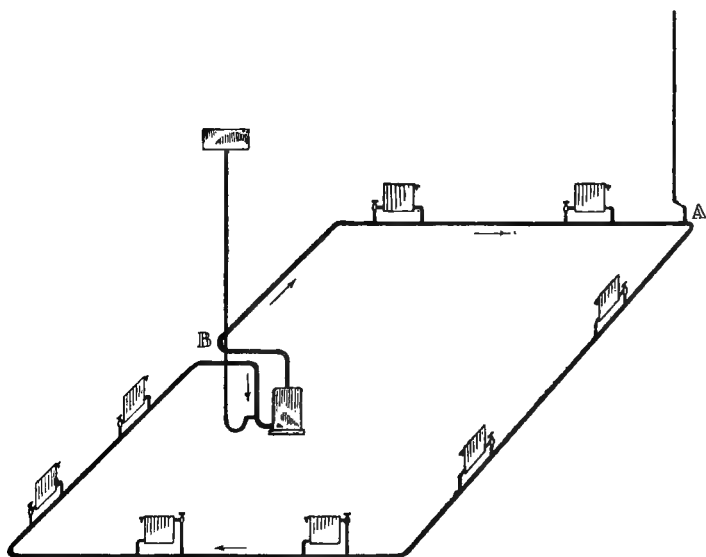


FIG. 262.—One pipe system.

main. In this system the cooled water from the heating surfaces mixes to a certain extent with the heated water from the boiler, and where a circuit is very long the water near the end may have a very low temperature. Where, however, the pipes are of a suitable size, the connections properly arranged, and the circuits not unduly long, the drawback mentioned is not so apparent, as the hottest water accommodates itself in the upper parts of the horizontal pipes, whilst the colder water occupies the lower portions.

To obviate any unnecessary cooling of the water in a *one*

pipe system, the returns from the heating surfaces should be joined at the side of the horizontal mains, in order that the colder water may be delivered directly to the lower parts.

It is important, when arranging mains, that no air locking shall take place, and to avoid this air-relief pipes require to be fixed at the highest points. Radiators when connected to horizontal pipes also require to be provided with some form of air relief.

In Fig. 262 the main from the boiler to point A constitutes the flow, whilst that part of the circuit from A to the boiler forms the return. The position B may also be made the highest part of the circuit, the return starting from that point.

The feed cistern of an apparatus is usually fixed in any convenient place above the highest heating surface, and the supply pipe may either join the boiler or the return pipe, as found most convenient. It is not necessary to fix a feed cistern more than a few feet above the top of the highest radiator, and to exceed this serves no useful purpose, but it subjects an apparatus to unnecessary strain.

With regard to the point where a flow-pipe should join a radiator, it matters little in many cases whether it be at the top or at the bottom of the radiator. Generally speaking, the best results are obtained by joining the flow-pipe to the top, although the bottom connection is the neater of the two, especially when the branch is rather large. The inlet of each radiator should be controlled by a stop valve, in order that the temperature of the water can be modulated as required.

When a building is two or more storeys high, a good method of piping for a *one pipe* system is that shown in Fig. 263. Where possible the heating surfaces on the upper and on the lower floors should be over one another, so as to reduce the number of risers which serve them. The return risers should join at the side of a main, whilst the flow riser in the majority of cases should be taken from the top. Each pair of risers forms a secondary circuit from the main circuit, and under ordinary conditions a good circulation through the risers is assured if they are correctly sized.

In Fig. 263 the boiler is assumed to be centrally placed, and to the left and right main circuits are provided. When a

building is large, the number of principal circuits can be increased, and this practice is commendable, as the circuits can be shortened, and better results obtained. One section can also be put out of use without interfering with the working of the remainder of the installation.

The cold water supply in Fig. 263 is shown joined at the end of one of the circuits, where an air-pipe is also provided.

A *one pipe* system has the special advantage of being

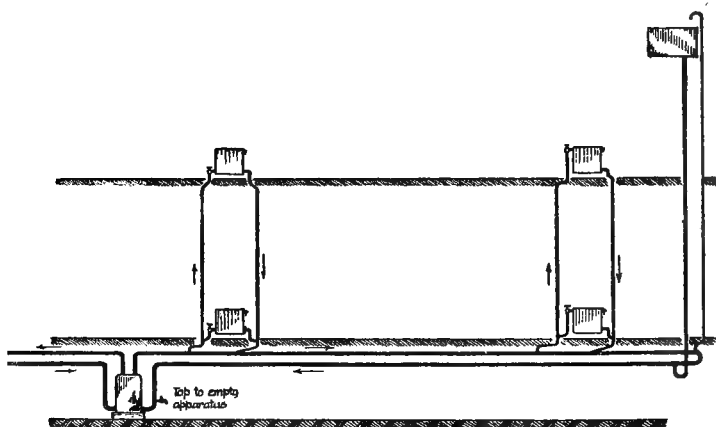


FIG. 263.—One pipe system with flow and return risers.

immune from short circuiting, and in consequence can be adopted where a *two pipe* system would result in failure.

A *two pipe* system is shown in Fig. 264, and the manner in which it differs from a *one pipe* system is in its circuit being graded and in the riser returns joining with the main return. The maximum size of the flow-pipe starts at the boiler, and its size is decreased as the heating surface is supplied, until the end of the flow is reached. From the latter point the circuit forms a return, and it is increased in size as the branch returns are joined with it. The chief drawback of a *two pipe* system is its liability to short circuit, and for a portion of a system to be either rendered useless or be very much impaired. *Short circuiting* takes place when too much resistance is encountered by the circulating water, and this may be due to

the improper grading of the pipes, to the latter being air bound, or to pipes being dipped or trapped.

The chief merit of a *two pipe* system, when well designed and properly installed, is that the cooled water from the heating surfaces is delivered directly to the return, instead of mixing with, and cooling, the heated water in the flow-pipe. This point is very important in large buildings where long circuits are imperative.

For a *two pipe* system to be a success, the pipes require to be properly sized, and well vented. Dips should be avoided

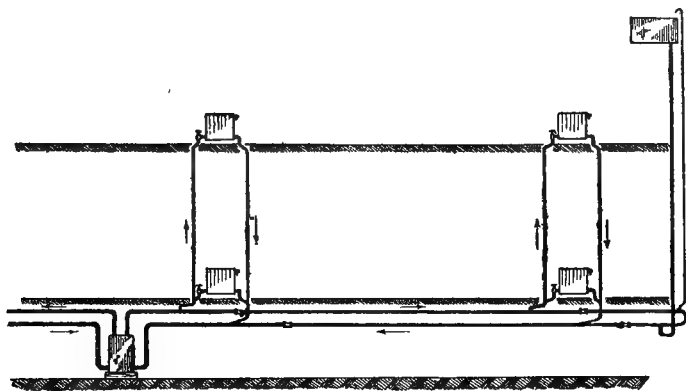


FIG. 224.—Two pipe system with flow and return risers.

as far as practicable and suitable fittings used, and unless these precautions are observed short circuiting will take place to a more or less extent.

Pitch of Pipes.—Where practicable, heating mains should have a pitch of 1 inch in 15 feet, and for small sized branches the pitch may be as much as half an inch per foot. When a main is of a comparatively small bore, a moderate pitch is necessary in order to keep it free from air.

Overhead or Drop System.—A very suitable method of piping for high buildings, and where the heating surfaces can be arranged to come above one another, is the down-feed or *drop* system, Fig. 265. In this system the flow-pipe rises directly from the boiler to a high elevation, where an air-pipe is provided. From the highest point one or more overhead

horizontal pipes are taken (depending upon the size of the building), and from the latter, vertical returns are dropped to pass close by the heating surfaces. No work, as a rule, is put upon the flow-pipe, and no other air reliefs in the form of valves or pipes may be necessary, other than that at the head of the flow-pipe. Air is chiefly given out from water when the

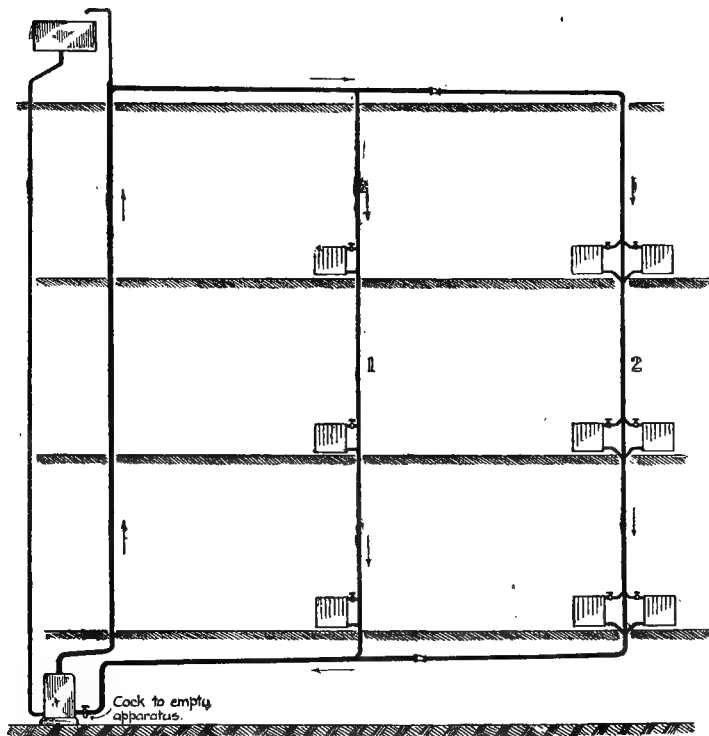


FIG. 265.—Overhead or drop system.

latter is heated, and the liberated air rises and escapes at the highest point. After the water leaves the boiler, a cooling action sets in, with the result that little or no air is given out from the water when in the return pipes. To the vertical return No. 1, horizontal connections are shown between it and the radiators, but these should only be short when this form of connection is adopted. A better mode of arranging the con-

nections is that on the vertical return No. 2, where long sweep tees are used which aid the circulation through the surfaces.

Owing to the large amount of vertical piping in an *overhead* system, a quick circulation is ensured, and in consequence the pipes can be smaller than in those systems where a greater proportion of horizontal pipes is used and where the circulation is slower. The horizontal overhead and low level returns require to be graded as regards their size, according to the amount of work put upon them. The single vertical pipes which serve the radiators are of uniform bore from end to end.

It frequently occurs when arranging the piping for an

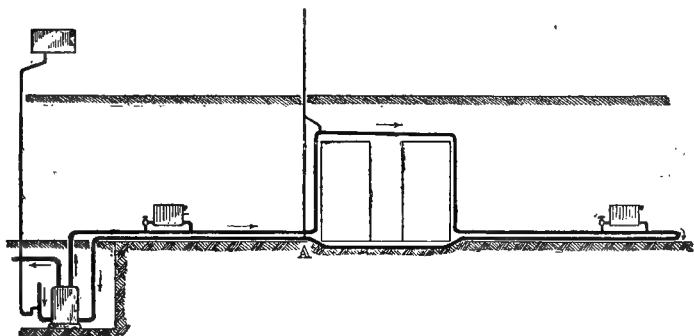


FIG. 266.—One pipe system where circuit dips beneath doorways.

installation that obstructions require to be passed. To attain this end the formation of one or more dips may be unavoidable, but as they impede circulation they should be avoided as far as possible. The best system of piping where dips are imperative is the *one pipe* system, but as regards the general arrangement of pipes for all cases no hard-and-fast rules can be laid down.

In Fig. 266 a case is shown where a couple of doorways come in the line of piping, and in order to pass them the flow-pipe is carried up and over them. The remaining part of the circuit from the air-pipe, forms a return, and instead of taking the latter back and over the doorways it is often dipped beneath them as shown. By fixing the flow-pipe over the doors as shown the circulating head is increased, and this

overcomes the extra resistance that is introduced by the trapped return. At A, Fig. 266, an air-pipe is shown in order to liberate air, which tends to gather at that point either when charging the apparatus or when the latter is in use.

The Circuit Height is the vertical distance between the highest part of a flow-pipe and the centre of the fire-box of the boiler, and the power to produce circulation is the difference in density between the ascending and descending columns which constitute the flow and the returns.

Another *one pipe* system is shown in Fig. 267, where the

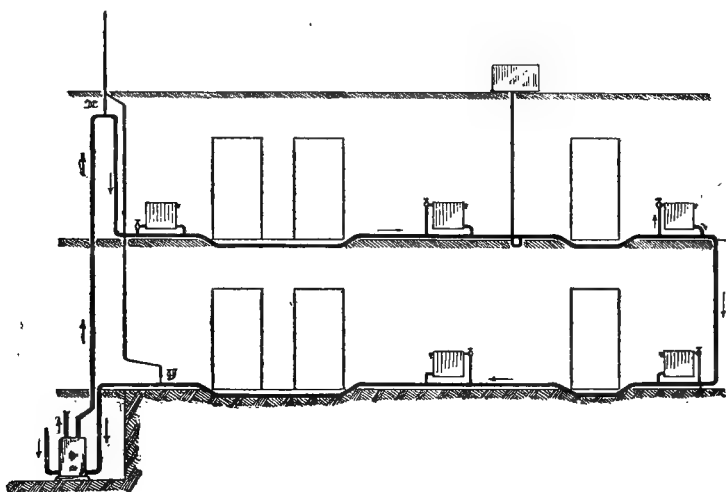


FIG. 267.—One pipe system where circuit dips beneath doors.

pipe requires to be dipped beneath a number of doorways. In this case radiators are fixed on each of two floors. The flow-pipe passes directly from the top of the boiler to the upper floor, and it is supposed to be carried up to near the ceiling in order to give extra power for circulating the water through the dipped circuit. Only two air-pipes are necessary, as at *x* and *y*, for any air which finds its way into any other part of the circuit will rise and accumulate in the radiators. From the latter, air can be periodically released by opening the air-cocks.

Sizes of Pipes.—The following table gives the approximate

amount of heating surface supplied by different sizes of pipes:—

TABLE XVI.

Internal diameter of pipe.	Square feet of surface, chiefly horizontal pipes.	Square feet of surface, horizontal and vertical pipes.	Square feet of surface, vertical pipes.
1 in.	40	50	75
1 $\frac{1}{4}$ "	75	90	130
1 $\frac{1}{2}$ "	130	150	250
2 "	230	360	600
2 $\frac{1}{2}$ "	360	500	800
3 "	520	650	1100
4 "	900	1280	2500
5 "	1600	2000	...
6 "	2300	3460	...
8 "	4600	6150	...
10 "	8000	10,400	...
12 "	11,520	14,000	...

With regard to the size of branches and radiator connections, these are given below.

Less than 50 sq. feet heating surface 1 in. diameter.

More than 50 " " and less than 80, 1 $\frac{1}{4}$ " "

Over 80 " " 1 $\frac{1}{2}$ " "

The sizes of branches should also be regulated by their general arrangement, for where they are rather long, and portions lie flat, they may advantageously be increased in size.

Heating Surfaces take the form of pipes, coils, and radiators. Either of the two latter is used when a large area of heating surface requires to be concentrated in a comparatively small space. Pipes are well suited for warming works and horticultural buildings, but for residences, offices, and similar buildings, radiators are also desirable.

Radiators usually have their surfaces vertically arranged, and they possess advantages over other forms of heating surfaces in that they are neater in appearance and collect less dust.

Radiators are made in many plain and ornamental forms, so as to suit any particular position in a building. The best type of radiator, when the heating surfaces are exposed, is the

column or loop class, where the sections are spaced to enable the whole of their surfaces to be readily cleansed. Fig. 268 gives a single column radiator by the Beeston Foundry Co., each section when 36 inches high contains $3\frac{1}{4}$ square feet of surface. Two and three column radiators of the same height contain per section 4 and $5\frac{3}{4}$ square feet of surface respectively.

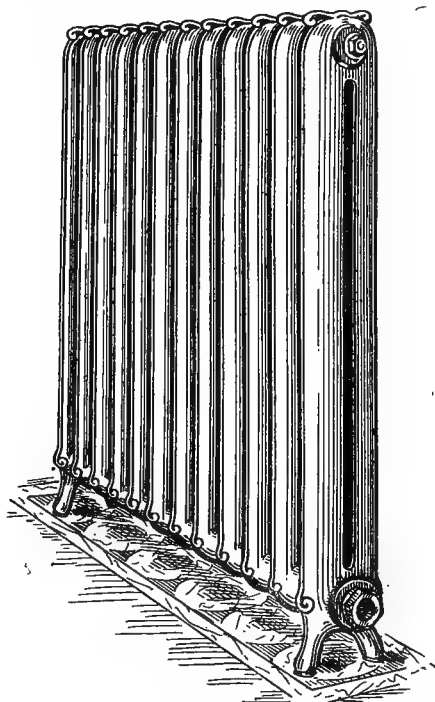


FIG. 268.—Single column radiator by the Beeston Foundry Co. Ltd.

There are two methods of joining the sections of radiators. One is by the use of tapered nipples, which are inserted in the upper and lower openings of the sections, and where wrought-iron tie rods are used to bind the sections together. The other, and better method, is by left and right-hand screwed nipples, the sections being tapped to suit.

For simple systems of ventilation, the cold inflowing air is often warmed by means of ventilating radiators. When a

good type of radiator is selected, this method of inlet ventilation is somewhat convenient, as the air supply can be readily controlled, but all parts should be arranged so as to admit of their being readily cleansed.

Fig. 269 shows a simple form of ventilating radiator. In

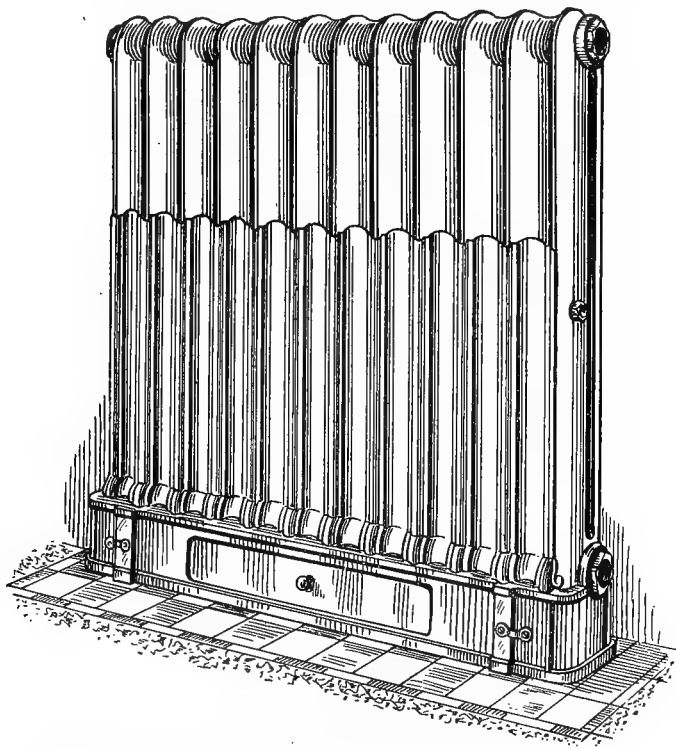


FIG. 269.—Ventilating radiator by the Beeston Foundry Co. Ltd.

this case baffle plates are fitted on both sides of an ordinary single column radiator, and a base is provided to admit fresh air at the back. The baffle plates are held in position by lugs which are cast on them, and they can be readily removed for cleansing purposes.

A ventilating radiator of the flue type is illustrated in Fig. 270, and the fresh air may be arranged to enter at the back as shown, or through the floor beneath. This radiator

is also designed that every part may be seen and be readily cleansed.

A drawback of many ventilating radiators, however, is their hidden parts, where dust and other matter can accumulate.

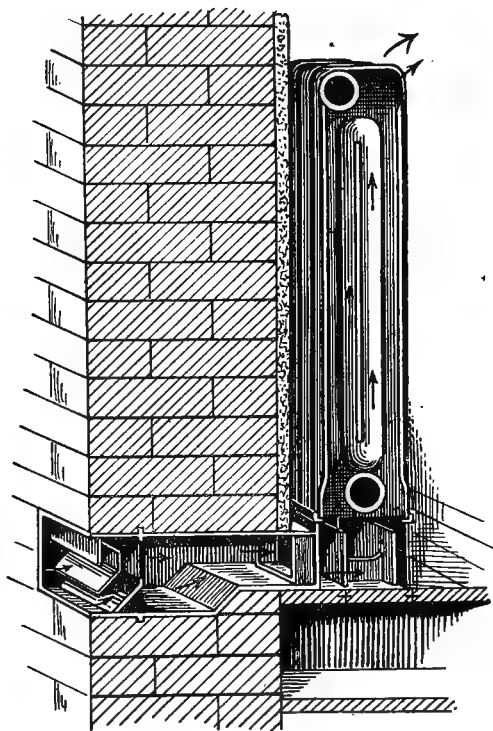


FIG. 270. -The "Marshall" ventilating radiator by the Beeston Foundry Co. Ltd.

For this reason ordinary loop radiators are often used, either with air grates immediately beneath them or in a wall behind. Of course when the ordinary type of radiator is adopted and where baffle plates are not used, the air is not warmed so well, and there is greater likelihood of draughts being felt. Fig. 271 gives a hinged radiator. This is a very useful form for

many situations, as it can be swung from the wall and so enable the space behind to be readily accessible.

Comparative Value of Heating Surfaces.—The relative amount of heat emitted by a surface largely depends upon the form it takes, the material of which it is made, and the position in which it is fixed.

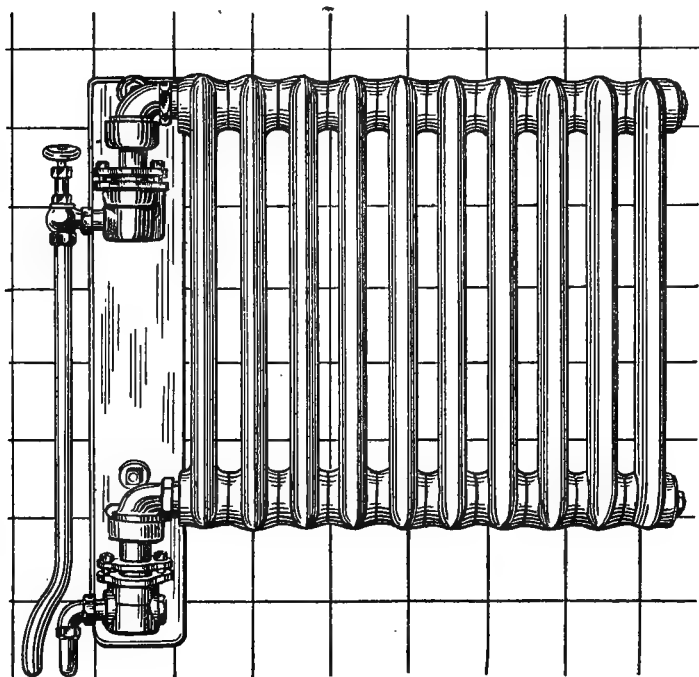


FIG. 271.—The "Hospital Hinged" radiator by the Beeston Foundry Co. Ltd.

When heating surfaces are exposed to view, the air of an apartment is warmed in two ways, viz. by radiant and by convected heat.

Radiant Heat passes from its source in straight lines, and is absorbed by the cooler surfaces of walls, furniture, and other objects. The intervening air space is not directly warmed by radiant heat, the rays passing through the air without

affecting its temperature. Air, however, in buildings always contains floating particles of matter which absorb a certain amount of heat, and these in turn give up some of the heat they have received to the air which envelopes them.

Convected heat is that which is absorbed by air coming in contact with heated surfaces, or by contact with objects which have been warmed by radiant heat.

Radiant heat can be intercepted by means of a short screen, whilst convected heat, which is conveyed by the circulating air, cannot be cut off by this means.

Small pipes emit more heat per unit area of surface than larger ones, when the difference in temperature between the pipes and the air surrounding them is the same, and when the rate of circulation is also equal.

Heating surfaces when grouped close together, such as in coils and radiators, emit less heat than where they are farther apart; in the former case a large percentage of the radiant heat is not utilised for warming purposes, as it cannot get away, but is simply radiated and re-radiated from surface to surface. The efficiency of heating surfaces is also affected by their height, for air currents, upon being warmed by contact at a low level, absorb less heat as they ascend. From the above it will be clear that the most efficient radiator is the low single column class, when the sections are a reasonable distance apart.

Polished copper, brass, or nickel-plated pipes emit less heat per unit area than other surfaces.

The positions in which the greater percentage of the heating surfaces should be placed are in the coldest parts of a building. These, obviously, are the windows, external walls, and near doorways. In buildings of considerable width it is necessary to fix heating surfaces in other positions than those stated, in order that warmth can be evenly distributed throughout the whole space.

Radiators should be fixed about 4 inches from walls where practicable, otherwise there is greater likelihood of the latter being soiled. Air, upon being warmed, leaves the heating surfaces with more or less considerable velocity, with the result that the particles of dust carried by the air strike

against any adjoining wall and discolour it. Discoloration of walls may be avoided by the use of light shields, which are occasionally placed on the tops of radiators so as to divert the air currents towards the centre of the apartments.

Radiator Valves.—A suitable pattern of valve for an

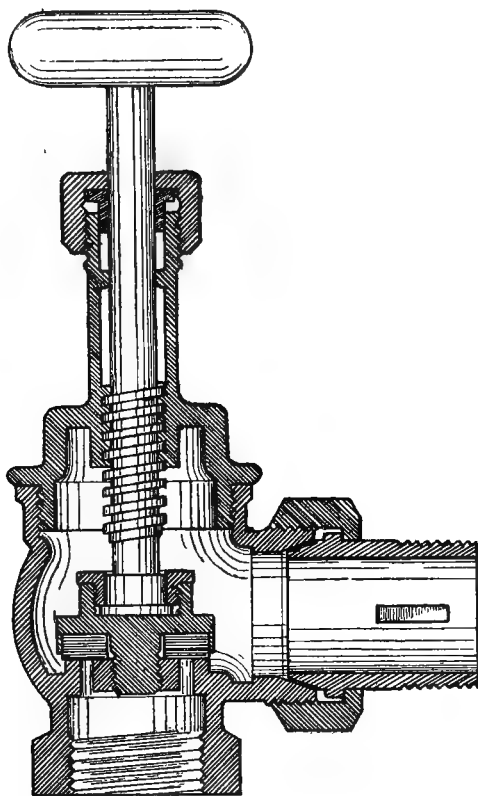


FIG. 272.—Angle valve by the National Radiator Co. Ltd.

up-feed system is that shown in Fig. 272, and it allows a neat and simple connection to be made. Whatever form of valve is used, one should be selected which does not unduly impede the movement of the water.

Air-Valves.—To admit of the escape of air from pipes and heating surfaces, air-valves are frequently used. These

may be divided into two classes: (a) Those which are periodically opened by hand; (b) those which are automatic in action.

The latter are suitable for a circuit where an open air-pipe cannot be used. A simple form of automatic air-valve is given in Fig. 273. Its action is as follows: If we assume that the valve is closed by the ball being partially submerged,

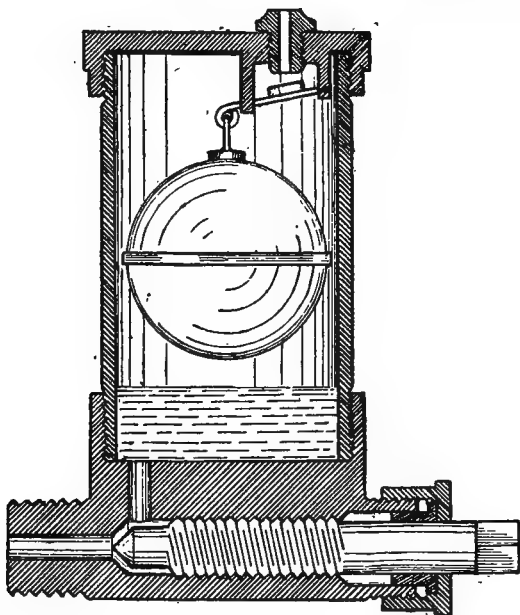


FIG. 273.—The "Ideal" automatic air valve by the National Radiator Co. Ltd.

the air passes through the water to the upper part of the valve. Should the accumulation of air continue, the water is displaced from the small pocket, when the ball falls by its own weight, opens the valve, and permits the air to escape. The discharge of air is followed by water and the ball is again buoyed up and the orifice closed.

Feed Cisterns.—The size of feed cisterns should be sufficient to accommodate the increased volume of water, when the latter is raised in the apparatus to its maximum

temperature. Approximately, water expands $\frac{1}{8}$ of its bulk when raised from 40° to 212° F. The highest water-line of a cistern should be a few inches beneath the overflow, but the ball-cock should be fixed so as to close when a cistern contains only a few inches of water.

As regards the size of a supply pipe which communicates between the feed cistern and the apparatus, this should not, as a rule, be less than 1 inch diameter. A dip or trap may be used in a feed pipe so as to prevent hot water circulating back to the supply cistern, but as a rule a dipped pipe is only necessary when the circulation is sluggish.

Calculation of Heating Surface.—Windows, roof lights, and external walls are the principal cooling surfaces in buildings, and the renewal of air by ventilation is also responsible for more or less considerable loss of heat. Doorways, ceilings, floors, internal walls and crevices, also account for loss of heat, and in countries where the cold is very intense these are also taken into account. In the British Isles, however, it is often sufficient to consider the principal heat losses, such as those due to glass surface, external walls, ventilation, and the exposure of buildings. To cover minor heat losses an allowance of 10 per cent. of the above is usually ample.

Discharge of Air through Flues.—To calculate the actual volume of air which will constantly pass through a flue or opening when the movement of air is dependent upon natural agencies is impossible.

The volume of air which will flow through an ordinary chimney varies considerably, the actual discharge being governed by the height, size, and form the flue takes, by the difference between the internal and external temperatures, by the freedom with which air can enter a room, and by the kind of walls in which the flues are formed. It is thus clear that discretion requires to be exercised when ascertaining the probable average discharge of air through any opening or extract shaft. On an average, when a fire is burning the discharge of air per sq. foot of flue area is about 11,000 cubic feet per hour.

If a building is already erected, the velocity of air through an opening can be determined by an air-meter, but the records will vary considerably. It is usual, however, to take a number

of readings, the mean velocity being used for the basis of calculation. In this case the volume of air discharged by a flue will equal the area of its cross section, multiplied by the mean velocity in feet.

When an air-meter cannot be used the following formula will aid in ascertaining the discharge of air through an upcast shaft:—

$$Q = 80 \times a \times \sqrt{\frac{h \times (T - t)}{460 + t}} \quad . \quad . \quad . \quad . \quad (88)$$

Where Q = discharge in cubic feet per hour.

„ a = area of cross section of flue in inches.

„ h = height of flue in feet.

„ T = temperature of air in flue.

„ t = external temperature of air.

Example 53.—If a 15 in. by 9 in. duct is 24 feet high, and the external and internal air temperatures are 45° and 60° F. respectively, determine the approximate volume of air this duct should discharge per hour.

$$\text{By Formula 88, } Q = 80 \times a \times \sqrt{\frac{h \times (T - t)}{460 + t}}$$

Substituting values given,

$$Q = 80 \times 15 \times 9 \times \sqrt{\frac{24 \times (60 - 45)}{460 + 45}}$$

$$Q = 80 \times 15 \times 9 \times .844;$$

$$\therefore Q = \underline{9115 \text{ cubic feet.}}$$

Assuming that a heating coil had been placed at the base of the duct in order to raise the escaping air to 80° F., the velocity of air through the shaft would have been increased. Under these conditions the discharge should be

$$Q = 80 \times 15 \times 9 \times \sqrt{\frac{24 \times (80 - 45)}{460 + 45}},$$

$$Q = 80 \times 15 \times 9 \times 1.289;$$

$$\therefore Q = \underline{13,921 \text{ cubic feet.}}$$

Heat to Warm Air.—To raise 1 cubic foot of air from 30° to 31° F. requires .01928 B.T.U., so that the volume of

air which can be raised through 1 degree by one heat unit will be $\frac{1}{\cdot 01928} = 51\cdot86$ cubic feet. In order to simplify matters we will take the latter value as 50 cubic feet, and this will be sufficiently accurate for practical work.

Thus the number of heat units necessary to make good the loss of heat due to ventilation can be obtained by multiplying the total volume of air in feet by the temperature through which the air is raised and by afterwards dividing by 50.

Heat absorbed by Walls.—The heat lost by walls varies according to their thickness, to the class of material used, to the treatment of their surfaces, whether cavities are formed in them or not, and according to their relative exposure. The values given by different authorities vary, but reliable information on this matter is that given in the German work by Recknagel and Rietschel. Tables XVII. and XVIII. are from that book, but the values are converted into English Units by Professor Kinealy and given in his book, *Formulas and Tables for Heating*.

TABLE XVII.

LOSS OF HEAT THROUGH BRICK WALLS IN BRITISH THERMAL UNITS PER SQUARE FOOT OF SURFACE PER HOUR, PER DEGREE DIFFERENCE OF TEMPERATURE, THE BRICKS BEING $8\frac{1}{2} \times 4 \times 2$ IN., WITH $\frac{3}{8}$ IN. MORTAR JOINTS

Thickness of wall.	Outside walls.		Inside wall, both sides plastered.	With additional stone face.			With air space of 2·4 inches plastered.
	No plaster.	One side plastered.		4 in. thick.	8 in. thick.	12 in. thick.	
$\frac{1}{2}$ brick .	·52	·49	·43	...	...	...	...
1 " .	·37	·36	·33	·31	·29	·26	·25
$1\frac{1}{2}$ " .	·29	·28	·26	·25	·23	·21	·21
2 bricks	·25	·24	...	·22	·20	·19	·19
$2\frac{1}{2}$ " .	·22	·21	...	·19	·18	·17	·16
3 " .	·19	·18	...	·17	·16	·15	·14
$3\frac{1}{2}$ " .	·16	·16	...	·15	·14	·13	·13
4 " .	·14	·14	...	...	...	...	·12
$4\frac{1}{2}$ " .	·12	·12	...	...	...	...	...

TABLE XVIII.

LOSS OF HEAT THROUGH STONE WALLS IN BRITISH THERMAL UNITS PER SQUARE FOOT OF SURFACE PER HOUR, PER DEGREE DIFFERENCE OF TEMPERATURE

Total thickness of wall.	Sandstone.	Limestone.	Total thickness of wall.	Sandstone.	Limestone.
12 inch	·45	·49	32 inch	·26	·28
16 "	·39	·43	36 "	·24	·26
20 "	·35	·38	40 "	·22	·24
24 "	·31	·35	44 "	·21	·23
28 "	·28	·31	48 "	·19	·21

HEAT LOST BY GLASS SURFACE

This is given in the following table along with other particulars. The values given by the two authorities differ a little, but not to any considerable extent:—

TABLE XIX.

Kind of surface.	Authorities.	
	Recknagel and Rietschel.	German Government standard.
Single windows . . .	1·09	1·03
Double " . . .	·472	·518
Single skylight . . .	1·092	1·118
Double " . . .	·492	·621
Doors . . .	·410	·414
Fireproof floor . . .	...	·124
" ceiling . . .	...	·145
Plaster 1·6 to 2·6 in. thick .	·615	...
" 2·6 to 3·2 in. " .	·492	...
(1)	(2)	(3)

The total heat lost in B.T.U. by walls and glass can be obtained by multiplying the exposed area, by the difference of the air temperature on the two sides, and afterwards by a suitable value from Tables XVII. to XIX.

According to Professor Rietschel the values in Tables XVII. and XVIII., and also those in column 2 of Table XIX., should be increased as stated below.

When the exposure is a northerly one, and the winds are important factors, increase by 10 per cent.

Where a building is heated during the daytime only, and is not an exposed one, increase by 10 per cent.

Where a building is exposed, and only heated during the daytime, increase by 30 per cent.

Where a building is heated intermittently during the winter months, and with long intervals of non-heating, increase by 50 per cent.

In order to arrive at the amount of heating surface to warm a building, we must next know how many heat units are emitted by such surface. The precise amount of heat emitted chiefly depends upon the form the surfaces take, and upon the difference in temperature between the surfaces and the atmosphere which envelopes them. The late Professor Carpenter of Cornell University, in his work *Heating and Ventilating Buildings*, gives the following values, which are reproduced in the table below:—

TABLE XX.

HEAT UNITS EMITTED PER SQUARE FOOT OF HORIZONTAL PIPE SURFACE PER HOUR, FOR DIFFERENT RANGES OF TEMPERATURE BETWEEN THE HEATING SURFACE AND THE AIR SURROUNDING THEM

Difference of temperature degrees F.	Total B.T.U. per square foot per hour.			
	Diameter of pipe,			
	6 in.	4 in.	2 in.	1 in.
40	49.6	56.2	59	77
50	64.5	73	77	100
60	79.8	90	95	124
70	95.2	108	113	148
80	112.0	127	133	173
90	128	147	153	199
100	147	167	175	228
110	166	188	198	257
120	184	208	219	287
130	203	230	242	318
140	223	252	266	346
150	244	276	291	378
160	265	300	316	410
170	286	324	341	443
180	307	348	367	475
190	330	375	393	512
200	356	403	415	552

The amount of pipe heating surface can now be obtained by first ascertaining the total heat losses per hour, and afterwards dividing by a value from Table XX. which agrees with the conditions given.

Example 54.—If a room contains 200 sq. feet of external sandstone wall which is 20 inches thick, 60 sq. feet of glass, and 10,000 cubic feet of air at a temperature of 30° F. are passed into it per hour, determine the area of 4-inch pipe surface which will maintain an internal temperature of 60° F. when the average temperature of the water in the pipes is 160° F.

Heat absorbed by Air.—The air required for ventilation is 10,000 cubic feet per hour, and to raise this from 30° to 60° requires

$$\frac{10000 \times (60 - 30)}{50} = \underline{6000 \text{ B.T.U.}}$$

Loss by Wall Surface.—In Table XVIII. the loss through a sandstone wall when twenty inches thick is .35 B.T.U. per sq. foot per hour per degree difference of temperature. The loss therefore by 200 square feet, when the difference in temperature between the internal and external surfaces is (60—30)=30°, will be

$$200 \times 30 \times .35 = \underline{2100 \text{ B.T.U.}}$$

Loss of Heat by Glass.—The heat lost by glass for an ordinary window according to column 3, Table XIX., is 1.03 B.T.U. per sq. foot per degree difference of temperature per hour. Therefore the loss due to 60 feet, when the difference in temperature between the two sides is (60—30)=30°, will be

$$60 \times 30 \times 1.03 = 1854 \text{ B.T.U.}$$

The heat absorbed by air, exposed wall, and glass equals
 $6000 + 2100 + 1854 = 9954 \text{ B.T.U.}$

Adding, for minor losses due
 to doorways, ceilings, floors,
 etc., 10 per cent. of the
 above = 995 B.T.U.

The total heat losses will equal 10,949 B.T.U.

determine the amount of heating surface, when single column radiators are used to maintain an inside temperature of 60° when the external air is 30° F. Average temperature of water in pipes 160° F.

$$\text{By Formula 89, } R = \frac{Q}{270} + \frac{W}{14} + \frac{G}{5}.$$

$$\text{Substituting values given, } R = \frac{10500 \times 3}{270} + \frac{870}{14} + \frac{250}{5},$$

$$R = 116.6 + 62.1 + 50.$$

$$\text{Total pipe surface} = 228.7 \text{ sq. feet.}$$

For single column radiators, plus

$$7 \text{ per cent.} \quad . \quad . \quad . \quad = 16.0 \text{ sq. feet.}$$

$$\therefore \text{total radiator surface} = \underline{244.7 \text{ sq. feet.}}$$

Heating Surface for Drying Rooms.—When low pressure hot-water apparatus is utilised for drying rooms, the following formula may be used for obtaining the heating surface required, to maintain an internal temperature of 80° when the outside air is 30° F., and when the average temperature of the water in the pipes is 170° F.:—

$$R = \frac{Q}{140} + \frac{W}{7} + \frac{I}{20} + \frac{G}{3} \quad . \quad . \quad . \quad . \quad . \quad (90)$$

Where R = total area of pipe surface in square feet.

„ Q = volume of air passed through room per hour.

„ W = area in feet of external walls.

„ I = area in feet of internal walls.

„ G = area of glass in feet.

To obtain satisfactory results in drying rooms, free ventilation is necessary, and the entering air should be diffused as evenly as possible throughout the whole of the space.

Example 56.—A drying room measures 20 feet in length 12 feet wide and 12 feet high. The area of the external wall surface is 144 sq. feet, and that of the internal walls 624 sq. feet. There is no glass. If the ventilating arrangement provides for 5 air changes per hour, find the heating surface required to give an inside temperature of 80° when the outside air is 30° F.

Using Formula 90, $R = \frac{Q}{140} + \frac{W}{7} + \frac{I}{20} + \frac{G}{3}$.

Substituting values given, $R = \frac{20 \times 12 \times 12 \times 5}{140} + \frac{144}{7} + \frac{624}{20}$

$$R = 102.8 + 20.5 + 31.2;$$

$\therefore R = 154.5$, say 155 sq. feet.

The area of a pipe surface may be found by *multiplying its circumference by its length*, or the following rule may be used:—

$$A = \frac{d \times 11 \times l}{42} \quad (91)$$

Where A=area of surface in feet.

„ d = external diameter of pipe in inches.

„ l = length of pipe in feet.

For approximations, it may occasionally be desirable to calculate the heating surface for warming a building from its cubic capacity. This method is not accurate, as the chief factors, such as exposed walls, glass surface, and ventilation, differ considerably in different parts of the same building.

The following Table gives the approximate number of cubic feet of space warmed to different temperatures by one square foot of pipe surface, when the outside air is about 30° F., and water in the pipes not less than 160° F.:—

TABLE XXI.

Kind of building heated.	Inside temperature Fahr.	Space warmed by 1 square foot of surface.
Workshops and factories . . .	50°	130 cubic feet.
Warehouses	55°	100 " "
Churches and large rooms . .	60°	86 " "
Living rooms	60°	58 " "
" " " " " "	65°	50 " "
Entrance halls	70°	42 " "
	75°	34 " "
Drying rooms	80°	27 " "
	85°	22 " "
	90°	18 " "

Boilers for Low Pressure Heating Apparatus.—For low pressure hot-water installations, independent cast-iron sectional boilers are displacing those of wrought iron, as the former are cheaper, and their heating surfaces can be more advantageously shaped and arranged. Brickwork settings are dispensed with, and sectional boilers also possess the advantage of portability, as they can be taken through narrow openings.

The selection of a boiler should be governed to a great extent by the class of fuel to be consumed. Where a fuel such as anthracite is used, smaller and more tortuous passages between the heating surfaces are permissible, provided the draught is suitable, in order to extract as much heat as possible from the fuel consumed.

Soft bituminous coals require a simple form of boiler, owing to the amount of soot deposited in the flues. All boilers require ample provision in the form of soot doors, to enable the heating surfaces to be periodically cleaned.

Heating surfaces of boilers are either *direct* or *indirect*; the former are exposed to the fire, and receive the flame impact, the radiant heat from the burning fuel, and the heated products of combustion. *Indirect* surfaces are those which do not face the fire, but receive their heat only from more or less flame impact, and the heated products of combustion. *Indirect* surfaces absorb considerably less heat than direct surfaces, but they are useful as they deprive the products of combustion of much heat, and prevent their escaping from the boiler at an unnecessarily high temperature.

In connection with *indirect* boiler surfaces there is a tendency to overvalue them. It is sometimes stated that the value of *indirect* surfaces is about one-third that of *direct* surfaces, but this valuation in most cases is considerably too high.

A general comparison of the value of *direct* and *indirect* boiler surfaces is unsatisfactory, for very much depends upon the ratio of the grate area to the heating surface and the design of the boiler. From a test made with a boiler which had a relatively large amount of indirect heating surface, the amount

of heat transmitted through each sq. foot of surface per hour worked out at 2500 B.T.U. The difference in value of the heating surface in contact with the fire and that most distant was considerable, and whilst a sq. foot of surface most favourably located would readily transmit 10,000 B.T.U. and over per hour, a sq. foot farthest removed would probably not transmit 250 B.T.U. in the same time. Thus, for this case, some portions of the indirect heating surface only have about one-fortieth the value of the best direct surface, area for area.

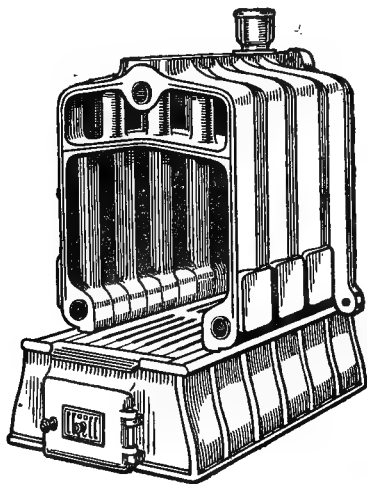


FIG. 274.—“White Rose” boiler by Hartley & Sugden Ltd.

Intermediate parts of the indirect surface would, of course, have a higher value, but the example will indicate the difficulty of assigning a true general value to the indirect heating surface of a boiler.

Fig. 274 gives one of Hartley & Sugden's cast-iron sectional boilers, where the sections are vertically arranged, and joined together by nipples and bolts. The upper part of each section is constructed to form centre and two side flues. At the fire-box the flames and heated products of combustion envelope, to a more or less extent, the surfaces immediately

overhead, and afterwards they pass into and along the upper side flues towards the front of the boiler, and thence through the centre flue back to the chimney. There are numerous waterways which increase the heating surface, and the grate area is proportional to the number of sections a boiler contains. This series of boiler is made in different sizes. Their lengths vary from 1 ft. 6 $\frac{3}{4}$ in. to 4 ft. 8 $\frac{1}{4}$ in., and the sections have a uniform width of 1 ft. 11 in., and they are catalogued to heat from 500 to 1700 sq. feet of radiator surface.

Another type of cast-iron sectional boiler by Lumbys Limited is given in Fig. 275. This is a larger type than that given in Fig. 274, and, as will be seen, contains proportionally more horizontal heating surface. The course of the flames, and products of combustion, after passing between the surfaces immediately over the fire-box, pass along towards the front of boiler, and thence to the chimney through the top horizontal flues. This pattern of boiler is made in various sizes, the greatest length being 7 ft. 6 in. and the shortest 2 ft. 10 in. The catalogue ratings of these boilers vary from 2880 to 7920 sq. feet of radiator surface. There are many makers of cast-iron sectional boilers, and the boilers illustrated are only intended to show the general form they take, not to infer that they are superior to those produced by other firms.

The "Trentham" Cornish boiler, Fig. 276, is suitable for large high buildings. It is circular in form, being made of $\frac{3}{8}$ -inch wrought-iron plates. For this boiler, brickwork settings are required, the flues being arranged that the heated products of combustion, after leaving the combustion chamber, can pass under the lower portion of the boiler towards the front, and afterwards back over the upper part to the chimney. A waterway bridge may be formed, and the heating surface can be further increased by providing cross tubes in the combustion chamber as shown. The "Trentham" boiler, owing to its shape, is suitable for withstanding high pressure, and it is made in sizes from 2 ft. 8 in. to 4 ft. diameter, and from 4 to 12 feet in length. These are catalogued as being capable of heating from 1080 to 6120 sq. feet of radiator surface.

A good draught is required for boilers with long and

tortuous flues, and the height of a chimney should well exceed the length of the horizontal travel of the products of combustion.

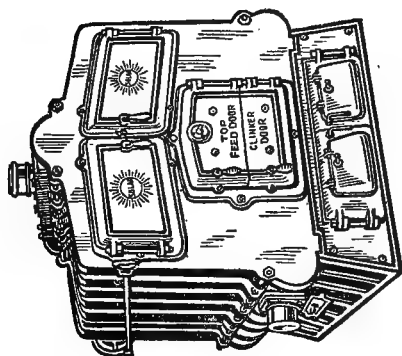


Fig. 275.—Solar boiler by Lumhys Limited.

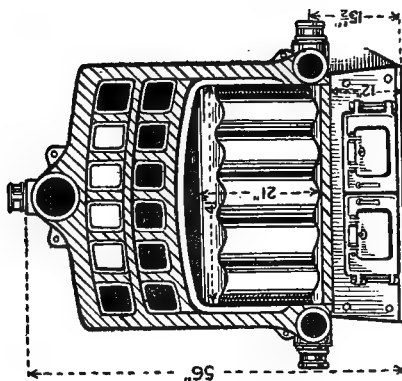
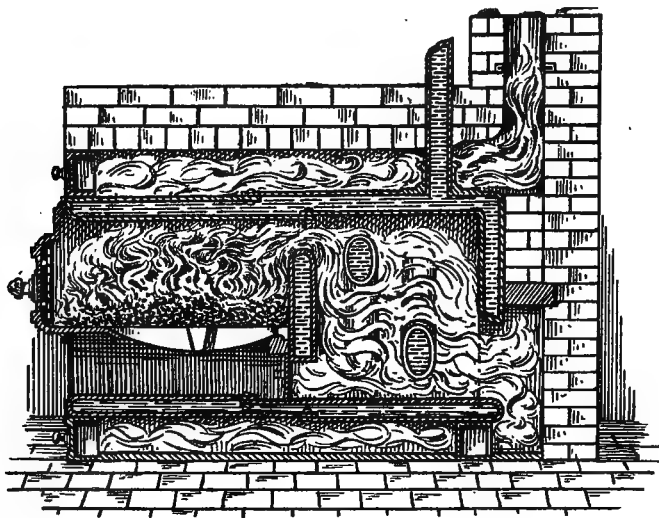
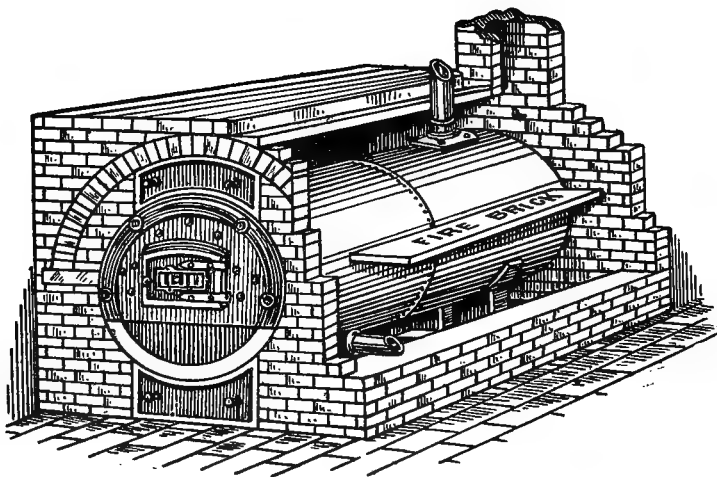


Fig. 277 gives a simple and effective form of wrought-iron boiler when the cross tubes are arranged in the manner shown.

The chief objection to this type of boiler is its height, and this limits its use on that account.



Section.



Elevation.

FIG. 276.—Trentham boiler by Lumbys Limited.

For a small heating installation, the dome-top boiler Fig. 246, or one of a similar grade, may be adopted. The drawback of this type is its low efficiency as a heater, but it has the advantage of a small initial cost. When the heating

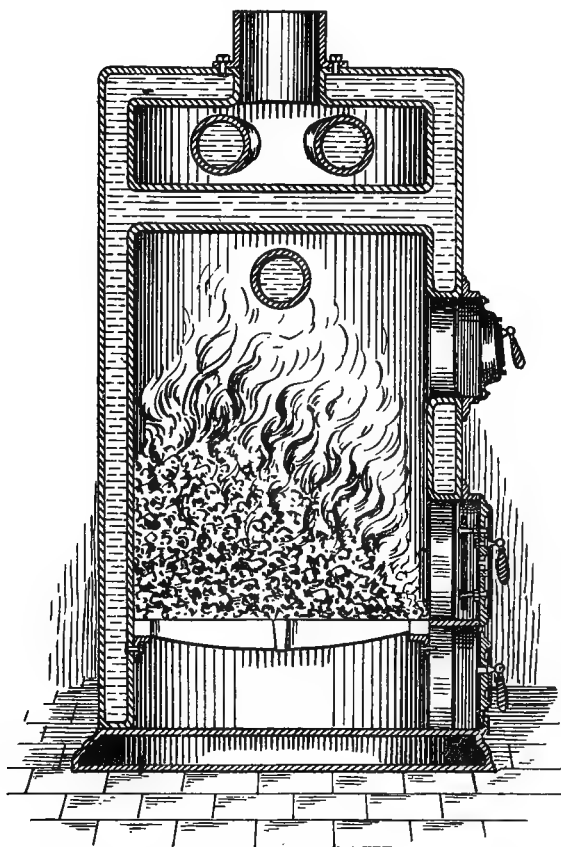


FIG. 277.—“Goliath” boiler by Lumby's Limited.

surfaces of a boiler are mainly of a vertical nature, and where there is a large clear passage to the outlet flue, a large portion of the heat given out from the fuel escapes into the chimney.

Boiler Draught Regulator.—An automatic device, which is

shown in Figs. 255 and 256, is very useful for controlling the draught of a boiler, and for economising fuel.

To prevent unnecessary loss of heat from boilers and main pipes, these should be covered with a good form of insulating material. Various substances are used for this purpose, but all allow a certain amount of heat to pass through them. -

Sizes of Boilers.—An old method of estimating the power of a boiler was to assume that each sq. foot of its surface would transmit sufficient heat to supply about 35 sq. feet of radiator surface. Taking the average amount of heat emitted by a single column radiator as 150 B.T.U. per sq. foot per hour, then each sq. foot of boiler surface should transmit $150 \times 35 = 5250$ B.T.U. per hour. For a normal rate of firing, the latter value is very much higher than can be obtained in practice, and as boilers vary very widely in construction it is a very inaccurate and misleading rule. The actual amount of heat that is transmitted by a sq. foot of boiler surface is not a fixed quantity, but depends upon—(a) the design of the boiler; (b) the ratio of the grate area to the heating surface; (c) the rate of firing; and (d) the class of fuel used. In operation, the condition of a boiler flue is also an important factor.

More failures have resulted in connection with heating systems through installing boilers which are too small than from any other cause. Most boiler catalogues are considerably overrated, but many makers introduce a kind of saving clause in which they recommend that a larger size be selected than the one listed to do the work required.

In the following Table is given the heat value in British thermal units per pound of different fuels (Molesworth's):—

TABLE XXII.

Coal average . . .	14,000 B.T.U.	Coal Lancashire (steam)	13,900 B.T.U.
„ Welsh (steam) .	16,000 „	„ Newcastle . .	14,000 „
„ Welsh (medium)	13,900 „	Coke	12,500 „
„ Scotch	13,500 „	Coke (gas)	10,000 „

It is not often that 50 per cent. and over of the heat in the fuel is transmitted through the surfaces of a low-pressure boiler, owing to the latter not being fired to advantage. The fuel is usually added at long intervals, the fire-box being sufficiently commodious in many cases to hold from 5 to 10 hours' supply. Very slow rates of combustion give a low efficiency, and for best results a moderately high rate of firing is imperative.

For obtaining the size of boilers the formulæ beneath are given—

$$a = \frac{R \times u}{w \times f \times c} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (92)$$

$$R = \frac{a \times w \times f \times c}{u} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (93)$$

Where a = area of boiler grate in feet.

„ R = total heating surface of radiators in sq. feet.

„ u = heat units emitted per hour per sq. foot of radiator surface.

„ w = weight of fuel in lb. consumed per sq. foot of grate.

„ c = a coefficient, the value of which depends upon the type of boiler and the rate of firing (see Table XXIII.).

„ f = heat value of fuel (see Table XXII.).

For two column radiators, the average value of u may be taken as 140, and for values of pipes see Table XX.

TABLE XXIII.

VALUES OF c FOR DIFFERENT FORMS OF HEATERS AND
DIFFERENT RATES OF FIRING

For good sectional self-contained boilers	$c = \cdot 5$ to $\cdot 65$
„ Cornish “Trentham” boilers	$c = \cdot 4$ to $\cdot 55$
„ vertical self-contained boilers with cross tubes	$c = \cdot 5$ to $\cdot 6$
„ self-contained dome-top boilers	$c = \cdot 35$ to $\cdot 45$

The fuel consumption w to agree with the values of c is also given. For very low rates of firing the values of c will

decrease, the rate of firing under ordinary working conditions varying from 3 to 12 lb. of fuel per sq. foot of grate per hour.

Boilers set in brickwork $w=5$ to 12 lb.

Sectional boilers with winding flues $w=6$ to 10 lb.

Self-contained vertical boilers $w=6$ to 10 lb.

Example 57.—If a system contains say 1500 sq. feet of radiator surface, and a good sectional cast-iron boiler is adopted, find size of boiler required to satisfy a rate of firing of 8 lb. of fuel per square foot of grate per hour. Assume the coal will yield 14,000 B.T.U. per lb.

$$\text{By Formula 92, } a = \frac{R \times u}{w \times f \times c}$$

For the rate of firing given, the value of c may be taken as .55.

$$\begin{aligned} \text{Substituting values, } a &= \frac{1500 \times 150}{8 \times 14000 \times .55}; \\ \therefore a &= \underline{3.65 \text{ sq. feet of grate.}} \end{aligned}$$

Should a higher rate of firing be adopted a smaller size of boiler would suffice, but the stoking would require to be done at shorter intervals.

For the boiler and conditions given in Example 57, the fuel consumed would amount to $3.65 \times 8 = 29.2$, say 30 lb. per hour.

Example 58.—The fire-grate of a boiler like Fig. 277 has an area of 1.8 sq. feet. Find the amount of radiator surface this boiler will serve, if coke, which has a heat value of 12,500 B.T.U. per lb., is the fuel burned, and when the rate of firing is 9 lb. per sq. foot of grate per hour.

$$\text{Using Formula 93, } R = \frac{a \times w \times f \times c}{u}$$

The value of c for this boiler (see Table XXIII.) for the rate of firing given may be taken as .5,

$$\begin{aligned} \text{and substituting values, } R &= \frac{1.8 \times 9 \times 12,500 \times .5}{150}, \\ \therefore R &= \underline{675 \text{ sq. feet.}} \end{aligned}$$

Chimneys.—Failure of boilers is occasionally due to defective draught owing to the chimneys being too small or

too short, containing too many bends or being formed of long lengths of exposed metal pipes.

Circular chimneys offer the least resistance, and for small boilers where a flue is formed of metal pipes, the minimum diameter should be 5 inches. Where possible, a boiler should be joined with a brick chimney, as the latter is less influenced by the weather. The effective area of a chimney is less than its actual area owing to the soot which accumulates on the surfaces.

To determine the size of a chimney for a heating installation, the following formulas may be used:—

For installations containing *less* than 700 sq. feet of heating surface

$$d = 0.5 \sqrt{\frac{R}{h}} + 2 \quad . \quad . \quad . \quad . \quad . \quad (94)$$

When an installation contains 700 sq. feet of heating surface and over

$$d = 0.5 \sqrt{\frac{R}{h}} + 1 \quad . \quad . \quad . \quad . \quad . \quad (95)$$

Where d = diameter of chimney in inches.

„ h = height of chimney in feet.

„ R = total heating surface of radiators and pipes in feet. Basis of heat emission 150 B.T.U. per sq. foot.

In the case of a square chimney, the length of one side may be considered equivalent to the diameter of a circular one.

Example 59.—Determine the size of a chimney when its height is 36 feet for a system containing 850 sq. feet of heating surface.

$$\text{By Formula 95, } d = 0.5 \sqrt{\frac{R}{h}} + 1.$$

$$\text{Substituting values given, } d = 0.5 \sqrt{\frac{850}{36}} + 1,$$

$$d = 6 + 1;$$

$$\therefore d = \underline{7 \text{ inches diameter.}}$$

APPENDIX

HYDRAULIC MEMORANDA

1 Imperial gallon of water	= 277·274	cubic inches.
1 cubic foot of water	= 62·37	lb.
1 „ inch „	= ·036	„
A column of water 1 inch square and 1 foot high	= ·434	„
A column of water 1 inch diameter and 1 foot high	= ·34	„
The capacity of a 1 foot cube	= 6·232	Imperial gallons.
The capacity of a tube 1 inch square and 1 foot long	= ·0434	„ „
The capacity of a tube 1 inch diameter and 1 foot long	= ·034	„ „
The capacity of a tube 1 foot diameter and 1 foot long	= 4·9	„ „
The capacity of a sphere 1 foot diameter	= 3·263	„ „
1 cubic foot sea water	= 64·001	lb.
1 „ inch „	= ·037	„
1 Imperial gallon	= 1·2	American gallon.
1 American „	= ·83	Imperial „
1 „ „	= 231	cubic inches.
1 cubic foot of water	= 7·48	American gallons.
1 Imperial gallon	= 4·543	Litres.
1 American „	= 3·8	„
1 cubic foot	= 28·375	„
1 Litre of water	= ·22	Imperial gallon.
1 „ „	= ·264	American „
1 „ „	= 61	cubic inches.
1 „ „	= ·0353	cubic foot.
1 cubic meter of water	= 220	Imperial gallons.
1 „ „	= 264	American „

WEIGHT OF A CUBIC FOOT OF WATER AT DIFFERENT
TEMPERATURES

Temp. deg. F.	Weight lb. per cub. ft.	Temp. deg. F.	Weight lb. per cub. ft.	Temp. deg. F.	Weight lb. per cub. ft.
32	62.42	110	61.87	190	60.31
35	62.42	115	61.81	195	60.2
40	62.42	120	61.71	200	60.08
45	62.42	125	61.65	205	59.93
50	62.41	130	61.56	210	59.82
55	62.39	135	61.47	212	59.64
60	62.37	140	61.38	220	59.58
65	62.34	145	61.29	230	59.31
70	62.31	150	61.2	240	59.03
75	62.27	155	61.1	250	58.75
80	62.23	160	60.99	260	58.46
85	62.18	165	60.84	270	58.17
90	62.13	170	60.78	280	57.88
95	62.07	175	60.66	290	57.58
100	62.02	180	60.55	300	57.26
105	61.96	185	60.43	400	53.63

WEIGHT OF A SQUARE FOOT OF DIFFERENT METALS, FROM
 $\frac{1}{16}$ INCH TO 1 INCH THICK, IN POUNDS

Thickness. inch.	Wrought iron.	Cast iron.	Steel.	Copper.	Zinc.	Tin.	Lead.
$\frac{1}{16}$	2.5	2.3	2.6	2.9	2.3	2.4	3.7
$\frac{1}{8}$	5.0	4.7	5.1	5.8	4.7	4.8	7.4
$\frac{3}{16}$	7.5	7.0	7.6	8.7	7.0	7.2	11.2
$\frac{1}{4}$	10.0	9.4	10.2	11.6	9.4	9.6	14.9
$\frac{5}{16}$	12.5	11.7	12.8	14.5	11.7	12.0	18.6
$\frac{3}{8}$	15.0	14.1	15.3	17.2	14.0	14.4	22.3
$\frac{7}{16}$	17.5	16.4	17.9	20.0	16.4	16.8	26.0
$\frac{1}{2}$	20.0	18.7	20.4	22.9	18.6	19.3	29.7
$\frac{9}{16}$	22.5	21.1	23.0	25.7	21.0	21.7	33.4
$\frac{5}{8}$	25.0	23.5	25.5	28.6	23.4	24.1	37.1
$\frac{11}{16}$	27.5	25.8	28.1	31.4	25.7	26.5	40.9
$\frac{3}{4}$	30.0	28.1	30.6	34.3	28.0	28.9	44.6
$\frac{13}{16}$	32.5	30.5	33.2	37.2	30.4	31.3	48.3
$\frac{7}{8}$	35.0	32.8	35.7	40.0	32.7	33.7	52.0
$\frac{15}{16}$	37.5	35.2	38.3	42.9	35.1	36.1	55.7
1	40.0	37.5	40.8	45.8	37.4	38.5	59.4

WEIGHT OF ONE SQUARE FOOT OF METALS

New stand- dard wire gauges. No.	Wrought iron. lb.	Steel. lb.	Copper. lb.	Tin. lb.	Zinc. lb.	Lead. lb.
1	11·92	12·24	13·7	11·32	11·23	17·75
2	10·97	11·26	12·63	10·42	10·35	16·45
3	10·02	10·29	11·53	9·52	9·45	15·03
4	9·22	9·47	10·61	8·76	8·70	13·83
5	8·43	8·66	9·70	8·01	7·95	12·64
6	7·63	7·84	9·78	7·25	7·20	11·44
7	6·86	7·04	7·90	6·52	6·48	10·29
8	6·36	6·53	7·32	6·04	6·00	9·54
9	5·72	6·13	6·58	5·43	5·40	8·58
10	5·08	5·22	5·85	4·83	4·80	7·62
11	4·61	4·73	5·31	4·38	4·35	6·91
12	4·13	4·24	4·75	3·92	3·89	6·20
13	3·66	3·76	4·21	3·48	3·45	5·49
14	3·18	3·26	3·66	3·02	3·00	4·77
15	2·86	2·94	3·30	2·72	2·70	4·30
16	2·54	2·60	2·92	2·41	2·40	3·81
17	2·14	2·19	2·46	2·03	2·02	3·21
18	1·91	1·96	2·20	1·81	1·80	2·86
19	1·59	1·63	1·83	1·51	1·49	2·38
20	1·43	1·47	1·64	1·36	1·35	2·14
21	1·28	1·31	1·47	1·22	1·24	1·92
22	1·11	1·14	1·28	1·05	1·04	1·66
23	·95	·97	1·09	·90	·89	1·43
24	·87	·89	1·00	·83	·82	1·30
25	·79	·81	·91	·75	·74	1·18
26	·71	·73	·82	·67	·67	1·06
27	·65	·67	·75	·62	·62	·97
28	·58	·60	·66	·55	·54	·87
29	·54	·55	·62	·51	·50	·81
30	·50	·51	·58	·47	·47	·75

WEIGHT OF CAST-IRON PIPES IN LBS. PER LINEAL FOOT

Bore. inches.	Thickness of metal.							
	$\frac{1}{4}$ in.	$\frac{3}{8}$ in.	$\frac{1}{2}$ in.	$\frac{5}{8}$ in.	$\frac{3}{4}$ in.	$\frac{7}{8}$ in.	1 in.	$1\frac{1}{8}$ in.
1 $\frac{1}{2}$	4·3	6·9	9·8	13·0	...	...	...	...
2	5·5	8·7	12·3	16·1	...	...	...	...
3	8·0	12·4	17·1	22·2	...	...	...	...
4	10·4	16·1	22·1	28·3	34·9	...	...	...
5	12·9	19·8	26·9	34·4	42·3	...	...	...
6	15·3	23·4	31·9	40·6	49·7	...	...	...
7	...	27·1	36·8	46·7	56·8	...	...	...
8	...	30·8	41·6	52·8	64·3	...	...	...
9	...	34·4	46·0	58·9	71·7	...	...	...
10	...	...	51·4	65·1	79·0	93·3	...	...
11	...	...	56·4	71·0	86·4	101·8	...	...
12	...	...	...	77·3	93·7	110·4	127·4	...
14	...	...	...	89·6	108·4	127·5	147·0	...
15	...	...	...	...	115·7	136·1	156·8	177·7
16	...	...	...	...	123·1	144·7	166·6	188·7
18	...	...	...	...	137·9	161·8	186·2	210·8

The above weights are for plain pipe ends. For either a socket or a flange joint allow 1 foot of pipe.

WIRE AND PLATE GAUGES

No.	Equivalent diameter or thickness in the fraction of an inch.			No.	Equivalent diameter or thickness in the fraction of an inch.		
	New standard wire gauge.	Birmingham wire gauge.	American wire gauge.		New standard wire gauge.	Birmingham wire gauge.	American wire gauge.
7/0	·500	...	...	21	·032	·032	·0284
6/0	·464	...	...	22	·028	·03	·0253
5/0	·432	...	...	23	·024	·025	·022
0000	·400	·454	·46	24	·022	·022	·02
000	·372	·425	·409	25	·02	·02	·018
00	·348	·38	·365	26	·018	·018	·016
0	·324	·34	·325	27	·016	·016	·014
1	·3	·3	·289	28	·014	·014	·0122
2	·276	·284	·257	29	·013	·013	·011
3	·252	·259	·229	30	·012	·012	·01
4	·232	·238	·204	31	·011	·01	·009
5	·212	·22	·182	32	·0108	·009	·008
6	·192	·203	·162	33	·01	·008	·007
7	·176	·18	·144	34	·009	·007	·006
8	·16	·165	·128	35	·008	·005	·0056
9	·144	·148	·114	36	·007	·004	·005
10	·128	·134	·102	37	·0068	...	·0044
11	·116	·12	·09	38	·006	...	·004
12	·104	·109	·08	39	·005	...	·0036
13	·092	·095	·072	40	·0048	...	·0032
14	·08	·083	·064	41	·0044	...	...
15	·072	·072	·057	42	·004	...	...
16	·064	·065	·05	43	·0036	...	...
17	·056	·058	·045	44	·0032
18	·048	·049	·04	45	·0028
19	·04	·042	·036	46	·0024
20	·036	·035	·032				

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